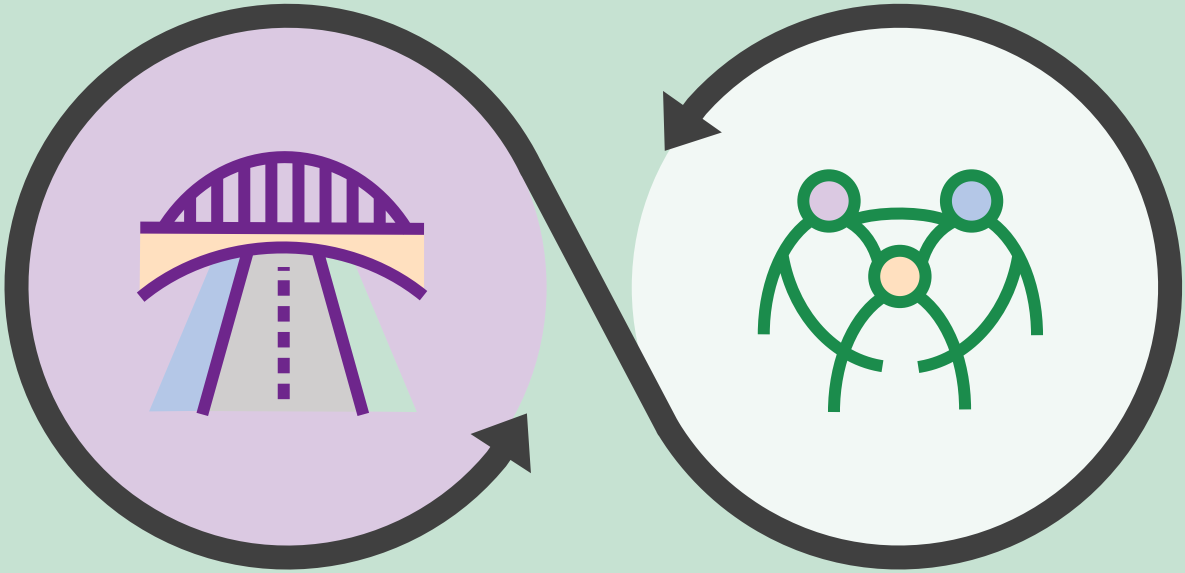

Tom Coenen

Governing the mission-oriented transition towards a circular infrastructure sector

From ideals to new socio-technical systems

GOVERNING THE MISSION-ORIENTED TRANSITION TOWARDS A CIRCULAR INFRASTRUCTURE SECTOR: FROM IDEALS TO NEW SOCIO-TECHNICAL SYSTEMS

Tom Bart Jacob Coenen

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Summary

Circularity has become a central pillar of future-proofing the infrastructure sector. Involving strategies to retain value and decrease environmental impacts through various resource loop principles, circularity encompasses new approaches to designing, organizing, and managing, fundamentally altering the infrastructure sector. Bio-based substitute materials in road construction, a modular approach to bridge design, and the reuse of sheet pile walls in rivers are a few examples of such circular civil engineering practices. Despite the ambitious goals to achieve a circular infrastructure sector, the actual implementation of measures that contribute to circularity lags behind. This implementation gap can be largely attributed to an isolated and technology-focused approach to circularity implementation. To address this gap, this research focuses on the interplay between infrastructure, social dynamics, and institutions, also known as a socio-technical system. As such, this dissertation views circular infrastructure from a socio-technical perspective.

When considering the fundamental change towards a circular infrastructure sector as a systemic socio-technical change, one can speak of transition. Such transitions are complex, multi-decade change processes that comprise major uncertainties. These systemic changes proceed with high interdependencies between and a co-evolving nature of physical elements (e.g., infrastructure assets and innovative materials), social elements (e.g., actors and relations), and institutional elements (e.g., sector culture and construction legislation). Given these transition characteristics, the objective of this dissertation is to generate the insights needed to further the transition towards a circular infrastructure. Accordingly, the dissertation sets out to address how socio-technical change towards a circular infrastructure sector can be anticipated and steered, indicating a comprehensive approach to understanding and managing the intricate and unpredictable nature of this socio-technical system. In doing so, the research question addressed in this dissertation is:

How can the mission-oriented transition towards circular infrastructure be governed?

This question is addressed in five individual yet interconnected studies that are each elaborated in a separate chapter. The main approaches and findings of these studies are summarized below.

Chapter 2 explores the systemic barriers hindering the transition towards a circular infrastructure sector, employing the Mission-oriented Innovation

System (MIS) framework. The interview-based analysis reveals three self-reinforcing vicious cycles: (1) the *circularity contestation cycle*; (2) the *knowledge diffusion cycle*; and (3) the *innovation cycle*. The circularity *contestation cycle* illustrates the fragmented understanding of circularity within the sector, leading to a lack of unified direction and slowing the adoption and upscaling of circular practices. This cycle is intertwined with the *knowledge diffusion cycle*, where limited circularity knowledge within organizations hampers learning and practical application, consequently impeding the upscaling of circular solutions. The *innovation cycle*, characterized by prescriptive procurement methods and a risk-averse sector culture, further hinders the adoption of more radical, innovative, circular alternatives. This underscores the need for systemic interventions to disrupt these cycles, emphasizing the need for a sectoral approach to overcome the barriers. Here, the contestation of the circularity concept stands out as a fundamental root cause affecting all cycles.

Investigating the perceptions of circularity in Dutch infrastructure, **Chapter 3** employs Q-methodology to understand the diversity of perspectives of infrastructure practitioners and their alignment with the formal circularity mission. The study identifies three clusters of perspectives that represent distinct socio-technical imaginaries. These imaginaries vary from a design-oriented perspective aimed at reducing waste to systemic revisions of infrastructure practices in order to lower environmental impact. Notably, these imaginaries diverge significantly from the formal government strategy, which might lead to ineffective implementation efforts. This results in the identification of two approaches for policymakers to deal with this contestation: (1) *constructive approaches* to converge understandings and (2) *agonistic governance* that embraces contestation to breach standstills acknowledging the divergent views. In conclusion, understanding and reconciling formal strategies and the various perspectives is crucial to effectively advance the circularity transition.

Addressing the question of how transitions towards a specific mission, such as circularity, can be governed, **Chapter 4** introduces the mission-oriented transition assessment (MOTA) as an approach to guide stakeholders in mission-oriented transitions. Building upon participatory, anticipatory, reflexive, and tentative governance modes, MOTA facilitates stakeholders in collectively appraising current and future socio-technical changes. Through socio-technical scenarios in the context of circular infrastructure in the Netherlands, the MOTA application reveals the dual role of infrastructure clients as both enactors and selectors of circular solutions. Moreover, results highlight the importance of balancing the feasibility of incremental changes and the need for radical solutions for circularity, advocating for frameworks such as *small wins* and *radical incrementalism*. Chapter 4 shows how the MOTA approach enables stakeholders, including policymakers, to deliberatively anticipate feasible steps towards a circular infrastructure, ensuring long-term transformative change.

With Rijkswaterstaat as a case organization, **Chapter 5** examines how infrastructure client organizations respond to institutional pressures resulting from the circularity mission. Using the concept of institutional logics, the study identifies tensions between existing organizational processes and upcoming circularity-focused activities. The research reveals that opportunities for circularity with the highest impact arise in the early stages of infrastructure management, while the logics that allow for circularity only come into play in the relatively fixed project stages. To effectively integrate circular principles, the research suggests a need for the deliberate engagement of circularity experts in the asset management and pre-project stages. The findings highlight the essential role of aligning different institutional logics within organizations to facilitate the integration of circularity in infrastructure management processes.

Finally, **Chapter 6** investigates how the *innovation ecosystem* concept can support collaborations to innovate for addressing circularity challenges in infrastructure. Based on innovation literature, the study identifies four critical traits of innovation ecosystems: (1) diverse actor involvement; (2) strategic actor alignment; (3) shared value propositions; and (4) relational governance. By examining unconventional, project-transcending initiatives in the Dutch infrastructure sector, findings suggest that innovation ecosystems, by fostering long-term, cross-sectoral relationships, are well-suited to introduce solutions that transcend traditional supply chains. However, adopting this perspective requires a cultural shift towards trust-based relationships and a reconfiguration of economic systems and business models. The chapter emphasizes the need for value-based contracting, partnering, and facilitating trust in collaborative transformations to address the long-term societal and sectoral challenges in circular infrastructure development.

Taking these chapters together, this dissertation addresses how socio-technical change towards a circular infrastructure sector can be governed. At the sectoral scale, the transition is identified as a collective challenge, necessitating an integrated response from all stakeholders. Government leadership is crucial, not in the sense of dictating each step, but in fostering convergence and awareness towards a unified circular future. This convergence is achievable through reflexive governance, integrating diverse perspectives and encouraging a reevaluation of established practices and norms. This approach, coupled with participatory, anticipatory, and tentative governance modes, forms a comprehensive framework to navigate the complexity and uncertainty of the transition.

The inter-organizational scale reveals that traditional public-private project-based approaches are inadequate for the interconnected nature of circular infrastructure challenges. A shift towards more relational, collaborative methods is essential. Framework agreements, alliances, and programmatic approaches emerge as promising strategies to overcome project-specific barriers and foster networks for industrial symbioses, crucial for establishing circular resource loops. These approaches demand a balance between long-term visions and the flexibility to adapt to evolving circumstances and interactions with other societal challenges.

On the organizational scale, the challenges lie in integrating circular principles within existing infrastructure management processes. Organizations must institutionalize processes that result in circular outcomes and embrace the societal challenge logic to ensure the comprehensive incorporation of circular solutions. This requires fostering an understanding across different organizational logics, promoting cross-departmental collaboration, and aligning asset management and planning processes with circular principles.

In conclusion, the transition to a circular infrastructure sector demands a nuanced, multi-level governance approach that integrates sectoral, inter-organizational, and organizational perspectives. This requires a guiding attitude from governments yet a collective effort from all stakeholders, including contractors, researchers, and suppliers, each playing a distinct but interconnected role. The complex and uncertain path forward requires embracing new governance modes, fostering collaborative relationships, and reimagining organizational practices to achieve a sustainable, circular future in infrastructure.

Samenvatting

Circulariteit is uitgegroeid tot een centrale pijler in de strategieën naar een toekomstbestendige infrasector, ook bekend als de grond- weg- en waterbouw (GWW). Circulariteit omvat strategieën die waardebehoud en milieu-impactreductie beogen door middel van verschillende principes die het vertragen, sluiten, versmallen en regenereren van materialencycli tot doel hebben. Deze strategieën vragen om nieuwe benaderingen voor het ontwerpen, organiseren en beheren van infra, welke fundamenteel nieuwe processen en werkwijzen vereisen. Voorbeelden van circulaire innovaties uit de Nederlandse praktijk zijn bio-based materialen in asfaltwegen, modulair brugontwerp en hergebruik van damwanden. Ondanks de ambitieuze (beleids)doelstellingen om een circulaire infra te bereiken, blijft de daadwerkelijke implementatie van maatregelen achter bij de doelen. Deze gebrekkige implementatie kan grotendeels toegeschreven worden aan een geïsoleerde en technologiegerichte aanpak rondom de huidige circulariteitsimplementatie. Om dit door een meer systemische bril te bekijken, kan de infra benaderd worden vanuit de wisselwerking tussen de fysieke infrastructuur, sociale dynamieken (o.a. relaties tussen actoren) en instituties (o.a. cultuur en regelgeving). Deze benadering staat ook bekend als een socio-technisch systeem. Dit proefschrift richt zich dan ook op de circulaire infrastructuur vanuit een socio-technisch perspectief.

Wanneer men de fundamentele verandering naar een circulaire infra benadert als een systemische en socio-technische verandering, wordt gesproken van een transitie. Dergelijke transities zijn complexe, meerjarige veranderprocessen vol onzekerheden, waarbij de co-evolutie van fysieke, sociale en institutionele elementen centraal staat. Het overkoepelende doel van dit proefschrift is om de transitie naar circulaire infrastructuur beter strategisch te navigeren, waarbij systemische belemmeringen naar boven gehaald moeten worden om passende aanpakken te ontwikkelen. Dit vereist een systemisch perspectief dat de complexiteit en onzekerheid, die inherent is aan dergelijke transities, omarmt. Zo beoogt het proefschrift de inzichten te verkrijgen die bijdragen aan het bevorderen van de transitie naar een circulaire infrasector. Daarbij wordt gekeken naar hoe socio-technische veranderingen naar een circulaire infrastructuursector kunnen worden voorzien en gestuurd, waarbij rekening wordt gehouden met complexe en onzekere aard van dit socio-technische systeem. Dit leidt tot de volgende centrale onderzoeksvraag:

Hoe kan de missie-georiënteerde transitie naar een circulaire infra worden gestuurd?

Hierbij wordt beoogd om zowel academisch publiek te bedienen met inzichten over de missie-georiënteerde aard van de circulariteitstransitie als beleidsmakers en koplopers in de sector met aanpakken en inzichten om de transitie te stimuleren en te sturen. De bovenstaande onderzoeksvraag wordt in de dissertatie middels vijf afzonderlijke studies beantwoord, die elk in een apart hoofdstuk zijn uitgewerkt. De afzonderlijke aanpakken en belangrijkste bevindingen worden hierna per hoofdstuk besproken.

In **hoofdstuk 2** zijn de systemische barrières onderzocht die de transitie naar een circulaire infra belemmeren, waarbij gebruik wordt gemaakt van het missie-georiënteerde innovatiesysteem (MIS) raamwerk. De analyse onthult drie vicieuze cycli die remmend werken op de transitie: (1) de *circulariteit-contestatiecyclus*; (2) de *kennis- en opschalingscyclus*; en (3) de *innovatiecyclus*. De contestatiecyclus illustreert de onenigheid, of contestatie, rondom het circulariteitsbegrip binnen de sector, wat leidt tot een gebrek aan eenduidige richting en het vertragen van de adoptie en opschaling van circulaire praktijken. Deze cyclus is verweven met de opschalingscyclus, waarbij beperkte capaciteit voor kennisborging en -diffusie van circulariteit binnen organisaties het leren en de praktische toepassing, en daarmee de opschaling, belemmert. De innovatiecyclus, gedreven door voorschrijvende inkoopmethoden en een risicomijdende cultuur, belemmert de adoptie van innovatieve circulaire alternatieven verder. Deze negatieve causaliteit toont de noodzaak aan om deze cycli te doorbreken met systemische interventies in plaats van slechts de symptomen te bestrijden. Hierbij valt de contestatie van het circulariteitsconcept op als een fundamentele belemmering die alle cycli beïnvloedt, en die daarom nader onderzoek behoeft.

In het onderzoek naar de contestatie van de percepties van circulariteit in de Nederlandse infra, maakt **hoofdstuk 3** gebruik van een Q-methodologie-aanpak om de verscheidenheid aan percepties binnen de infrapraktijk en de aansluiting op de formele circulariteitsmissie beter te begrijpen. Op basis van 34 infraprofessionals zijn drie clusters van perspectieven geïdentificeerd die verschillende socio-technische percepties vertegenwoordigen. Deze percepties variëren van een ontwerpgerichte aanpak voor circulaire infrastructuur gericht op afvalvermindering tot systemische herzieningen van infrastructuurpraktijken om de bredere milieu-impact te verlagen. Opvallend is dat deze percepties aanzienlijk afwijken van de formele overheidsstrategie. Deze richt zich voornamelijk op regulering en standaardisatie en hier zijn de door professionals geprioriteerde oplossingen grotendeels afwezig. Het hoofdstuk suggereert twee governance-benaderingen om met deze contestatie om te gaan. Een ‘constructieve benadering’ helpt om begrip te kweken en de verschillende perspectieven op circulariteit te convergeren. Daarnaast kan de ‘agonistische benadering’ gebruikt worden wanneer afstemming onhaalbaar wordt geacht.

De bevindingen benadrukken de fundamentele moeilijkheden van de uiteenlopende perspectieven en roepen op tot een actievere afstemming van formele strategieën met de verschillende perspectieven om de overgang naar circulariteit te bevorderen.

Op basis van de inzichten in de systemische barrières, is in **Hoofdstuk 4** het missie-georiënteerde transitie-assessment (MOTA) raamwerk ontwikkeld als een benadering om infra-actoren beter in staat te stellen om strategisch te handelen en beleid te informeren in missie-georiënteerde transities. Voortbouwend op participatieve, anticiperende, reflexieve en tentatieve governance-modi faciliteert MOTA-belanghebbenden in de beraadslagende anticipatie van huidige en toekomstige socio-technische veranderingen. Middels socio-technische scenario's in de context van circulaire infra in Nederland, benadrukte een georganiseerde MOTA-workshop de dubbele rol van opdrachtgevers in de infra als zowel uitvoerder (*enactor*) als beoordelaar (*selector*) van circulaire oplossingen. Daarnaast laten de resultaten het belang zien van het balanceren van incrementele en radicale oplossingen voor circulariteit om zowel het systemische karakter van transities als de haalbaarheid te waarborgen. Governance-aanpakken als het *small wins* raamwerk en *radicaal incrementalisme* bieden hiervoor goede aanknopingspunten. Hoofdstuk 4 laat zien hoe de MOTA-benadering belanghebbenden, inclusief beleidsmakers, in staat stelt om te anticiperen op haalbare stappen naar een circulaire infrastructuur doordacht en in onderlinge beraadslaging, waarbij zorg wordt gedragen voor langjarige en radicale missiedoelstellingen.

Zulke missie-georiënteerde transities hebben grote implicaties voor individuele organisaties. Met Rijkswaterstaat als casusorganisatie, is in **hoofdstuk 5** onderzocht hoe opdrachtgevers in de infra omgaan met de institutionele druk als gevolg van de circulariteitsmissie. Met behulp van het *institutional logics*-concept identificeert de studie spanningen tussen bestaande organisatorische processen en nieuwe, op circulariteit gerichte activiteiten. Zulke *logics* vertegenwoordigen een bepaald gedeeld waarde- en handelingskader voor individuen. Het onderzoek laat zien dat terwijl kansen voor circulariteit met de grootste impact op de infra zich in de vroege stadia van infrastructuurbeheer voordoen, de *logics* die circulariteit ondersteunen pas in de relatief late en rigide projectfasen dominanter worden. Om circulaire principes effectief te integreren, roept het onderzoek op tot het doelbewust meenemen van circulariteitsexperts in de fasen van asset management en in de pre-projectfasen. De bevindingen benadrukken het belang van het afstemmen van verschillende *institutional logics* binnen organisaties om de integratie van circulariteit in assetmanagement-processen te vereenvoudigen.

Tot slot is in **hoofdstuk 6** onderzocht hoe het concept van innovatie-ecosystemen samenwerkingen in de infra kan ondersteunen om te innoveren ten behoeve van langjarige maatschappelijke uitdagingen zoals circulariteit. Middels een literatuurstudie zijn vier fundamentele kenmerken van innovatie-ecosystemen onderscheiden: (1) diverse betrokkenheid van actoren; (2) strategische afstemming tussen actoren; (3) gedeelde waardeproposities en (4) relationele governancestructuur. Vijf onconventionele, projectoverstijgende initiatieven in de Nederlandse infra zijn onderzocht op basis van de vier kenmerken. De initiatieven laten zien hoe ecosysteem-denken, door het bevorderen van langdurige en sectoroverschrijdende relaties, de potentie heeft om circulaire oplossingen te introduceren die traditionele projectstructuren en toeleveringsketens overstijgen. Het aannemen van het ecosysteemperspectief vereist echter een cultuurverandering naar op vertrouwen gebaseerde relaties en een herziening van de huidige economische systemen en bedrijfsmodellen binnen de sector. Het onderzoek benadrukt de potentie van contractering op basis van gedeelde waardepropositie, partnerschap en het faciliteren van langdurige samenwerking om maatschappelijke en sectorale uitdagingen in de ontwikkeling van circulaire infrastructuur aan te pakken.

Dit brengt ons terug bij de hoofdonderzoeksvraag hoe de missie-georiënteerde transitie naar een circulaire infra kan worden gestuurd. Ondanks de eenduidige roep voor een leidingnemende overheid, wordt de transitie op sectoraal niveau geïdentificeerd als een collectieve uitdaging, die een collectieve respons van alle belanghebbenden vereist. Leiderschap vanuit de overheid is hier cruciaal – niet door het opleggen van elke stap, maar met het organiseren en sturen van convergentie en bewustzijn naar een afgestemde circulaire toekomst. Deze convergentie is haalbaar door reflexief bestuur, het integreren van diverse perspectieven en de durf om de gevestigde praktijken en normen te herzien. Deze aanpak, gekoppeld aan participatieve, anticiperende en tentatieve governance-modi, vormt een integraal kader om de complexiteit en onzekerheid van de transitie te navigeren.

In de samenwerking tussen organisaties blijkt dat traditionele publiek-private, projectafhankelijke benaderingen ongeschikt zijn om de onderling verbonden aard van circulaire infrastructuuruitdagingen aan te pakken. Een verschuiving naar relationele, collaboratieve methoden is hiervoor essentieel. Raamovereenkomsten, allianties en programmatische benaderingen komen naar voren als veelbelovende startpunten om project-specifieke barrières te overwinnen. Daarnaast kunnen deze aanpakken bijdragen aan het vormen van netwerken die industriële symbiose bevorderen, cruciaal voor het bewerkstelligen van circulaire materialencycli. Deze benaderingen vereisen een zorgvuldige balans tussen coherente langetermijnvisies en de flexibiliteit om zich aan te passen aan veranderende omstandigheden.

Op organisatieniveau ligt de uitdaging in het integreren van circulaire principes binnen bestaande infrastructuurbeheerprocessen. Organisaties dienen nieuwe processen hiervoor te institutionaliseren die resulteren in circulaire uitkomsten. Dit vereist het bevorderen van begrip tussen personen die verschillende *institutional logics* aanhangen, het stimuleren van samenwerking tussen afdelingen en het afstemmen van asset management en infraplanning met circulaire principes.

Concluderend vereist de transitie naar een circulaire infra een genuanceerde, multi-level governance-aanpak, die sectorale, interorganisatorische en organisatorische perspectieven integreert. Dit vereist een collectieve inspanning van alle belanghebbenden, waaronder de overheid, aannemers en toeleveranciers, waarbij elk een onderscheidende maar onderling verbonden rol speelt. Het complexe en onzekere pad voorwaarts vraagt om nieuwe governance-modi, het bevorderen van collaboratieve relaties en het heroverwegen van organisatorische praktijken om een duurzame, circulaire toekomst in de infra te bereiken.

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List of acronyms

CB'23	Circular Building 2023 platform
CE	Circular Economy
EZK	Ministry of Economic Affairs and Climate
IenW	Ministry of Infrastructure and Water Management
MIP	Mission-oriented innovation policy
MIS	Mission-oriented innovation system
MLP	Multi-level perspective
MOTA	Mission-oriented transition assessment
RQ	Research question
STS	Science, Technology, & Society studies
TA	Technology assessment
TIS	Technological innovation system
TRL	Technology readiness level

Preface

As I started a long-distance trail in the United States, fresh from successfully defending my Master's thesis, I received an email from my thesis supervisor, Professor Joop Halman. In the e-mail, there was the question of whether I would be interested in an Engineering Doctorate focused on the circular design of bridges and viaducts. It was an opportunity that seemed tailor-made to mobilize my background in Civil Engineering and exploit my interests in construction management and sustainability. For two intensive years, I delved deeply into developing an indicator to quantify the degree of circularity within bridge design. As per the metrics of my circularity indicator, it was suggested that circular bridge designs were technically feasible, yet bridges and viaducts continued to be conceived, constructed, and managed in a non-circular fashion. There must have been something else at work here.

Increasingly puzzled by the question of why circular infrastructure is still built in linear ways while many of the technological solutions are already at hand, it turned out that practitioners were bothered by similar challenges. Rijkswaterstaat, the very entity financing my Engineering Doctorate, decided to allocate funds for a full-scale PhD project. The objective? To increase understanding of how to shape the circularity transition in the sector. This position enabled me to study the transition from a systemic perspective and allowed for probing into specific organizations, processes, and practices to inform the sectoral transition.

While being interested in the sociological and institutional theories, I started with quite an engineering attitude: just look at what the barriers to the transition are and design solutions to tackle those barriers. Soon, practice turned out to be too unruly for such an approach. With the guidance of Leentje Volker and Klaasjan Visscher, this compelled me to reevaluate the research approach and inquire into the nature of knowledge and truth that I, as a researcher, could realistically grasp. Figures like Max Weber and George Mead initially captivated me with their assertion that all knowledge is inherently socially constructed. This view resonated deeply, given the contentious nature of circularity and the pivotal role of social interactions in transitions. Nevertheless, this research philosophy insufficiently provided me with the insights necessary for addressing the grand questions surrounding the sectoral transition toward circularity. This unquestionably demands a degree of systemic thinking.

A central thread running through my dissertation thus draws upon a critical realist perspective. This perspective acknowledges the existence of the actual transition, albeit covered by complexity that impedes complete comprehension. In most chapters, specific and often tailored lenses or frameworks are used or developed to make sense of these transition developments in reality. In hindsight, this philosophical journey becomes evident when examining the submission dates of the published chapters, revealing a gradual shift from an engineering mindset toward one rooted in qualitative social science – a personal transition. Allowing several side-steps into organizational sciences and Science, Technology, and Science (STS) studies, the PhD journey has slowly tilted my worldview towards one that much more appreciates the complexities between the physical world, human behaviour, and institutions that guide behaviour.

That being said, my background as a civil engineer has been of great value at all stages of the research. Whether engaging with project engineers, managers, or policymakers, my grounding in civil engineering facilitated data collection and analysis by fostering an acute understanding of the domain-specific context.

This process has accumulated into the dissertation that lies before you. It provides an account of the transition at a sectoral circularity transition, considering past, present, and future and occasionally delving into specific issues. While conducting the various researches, the topic of a transitioning circular infrastructure sector appeared to be a unique domain for the sector's public nature and project-based activities as well as the systemic consequences of circular transition for the sector. This allowed me to not only use theories, concepts, and lenses to execute the studies in the domain but also to feed back into theory. The result is a collection of research that draws from and adds to various scholarly fields.

From the journey on that long-distance trail, little did I know that an email would set me on a path filled with such an unexpected journey. In those initial moments, I could not have foreseen the incredible journey ahead. However, these unexpected opportunities and challenges in particular have shaped my path, and I am grateful for every twist in the trail.

chapter 1

introduction

1.1 Introduction

Associated with strategies to close, narrow, slow, and regenerate resource loops, circularity is often used as an alternative systemic approach to retain value and decrease environmental impact (Kirchherr, et al., 2023). For its massive use of materials in, e.g., roads, dikes, railways, and pipes, the infrastructure sector is often considered a key sector in pursuing a circular economy (CE). Compared to the infrastructure sector in its current form, this means that a future circular sector has radical new ways of, for example, designing, organizing, and regulating (Joensuu et al., 2020). This presumes new and changing actor roles and interactions (Wittmayer et al., 2017). In other words, a circular infrastructure sector implies a fundamentally different socio-technical system, indicating a novel configuration of technologies, regulations, actors, services, and infrastructure (Schot et al., 2016). As a result, circularity will turn the infrastructure sector upside down.

Circularity is presented in the Netherlands as a transformative mission, which contains a collection of time-bound objectives and strategies. This includes environmental impact reduction statements and minimum material reuse percentages. Despite a rapidly increasing number of circularity-oriented innovations in the infrastructure sector, the circular outcomes of current infrastructure practices are still way short of the mission’s objectives (PBL, 2023). To illustrate, only an estimated 8% of the material input in the built environment consisted of reused materials, while the mission’s objective is to achieve a 50% reuse by 2030 (Circle Economy, 2022).

In this dissertation, I argue that this gap between the mission’s objectives and the realization in practice results from considering the circularity implementation efforts too much in isolation and too much as technological challenges. A more systemic understanding of circularity implementation can be interpreted in two ways. On the one hand, a circular infrastructure system can be understood from a perspective of material flows from and to infrastructures (i.e., resource perspective). On the other hand, it can be approached from a perspective of interdependencies between physical infrastructure, social dynamics, and institutions (i.e., socio-technical perspective). While the resource perspective is increasingly studied (e.g., Bucci Ancapi et al., 2022; Yu et al., 2023), the socio-technical view thus far remains largely unexplored.

One can only explain how to better steer for circularity once the circularity efforts are understood in coherence with their social and institutional contexts. A striking example is the Circular Viaduct, which was developed between 2016 and 2019 and has been operational for only half a year. The viaduct was designed modularly using uniform, pre-cast concrete segments. Supported by widespread media attention, these were successfully assembled into a viaduct to serve on a construction site and were disassembled afterwards as planned. However, the segments were never reused post-pilot due to their lack of alignment with prevailing technical norms, environmental impact definitions, and conventional ownership distribution (Rijkswaterstaat, 2019). So, even though the viaduct aligns well with the design principles of circularity, one may ask how circular the long-term outcomes are. This illustration shows that becoming circular as an infrastructure sector requires more than a collection of technological, stand-alone innovations.

Alternatively, I will treat the pursuit of a circular infrastructure sector as a socio-technical change process to take the steps necessary to achieve an inherently circular sector. Such change processes are known as socio-technical transitions. We know from the field of Sustainability Transitions that such innovations probe deeper social and institutional structures and cannot be seen in isolation (e.g., Geels, 2005; Rip, 2012). These transitions, however, are multi-decade, inherently complex, and highly unpredictable (Köhler et al., 2019). The complexities and uncertainties involved in this systemic view make the transition towards a circular infrastructure sector hardly predictable or manageable (Smith et al., 2005). Instead, insights into the socio-technical dynamics must be used to offer reflexive and anticipatory guidance to move the sector toward the CE mission (Truffer et al., 2010). However, how such mission-oriented transitions can best be steered and governed is still heavily debated (Janssen et al., 2021).

Past research on circular infrastructure focuses at the individual, often technical aspects of circularity. However, to govern the transition towards circular infrastructure, those aspects must be considered in coherence with the social and institutional aspects. To address this gap, I dedicate this dissertation to providing analyses and approaches to promote the next steps in achieving systemic change towards a fundamentally circular sector. Given the socio-technical view required to consider these complexities and uncertainties, the research is primarily conducted from governance and management perspectives. Accordingly, this dissertation aims to help academics, policymakers, and industry leaders make better choices for a more effective and desirable future of circular infrastructure.

In the remainder of this introduction chapter, I will first introduce the dissertation's context of the transition towards circular infrastructure. Next, I will discuss the objective of the research as well as the positioning of the research approach. This is followed by an introduction to the research questions and approaches of the separate studies. This chapter concludes with the dissertation's outline.

1.2 Circularity transitions in infrastructure

The research in this dissertation combines the domains of circularity, infrastructure, and transitions. Three main areas come together in this dissertation that, collectively, comprise the gap of considering circular infrastructure as a transition. The domain of study is the infrastructure sector, which embodies unique characteristics that heavily affect both the potential circular innovations and change dynamics. Here, circularity, and especially the formal circularity policy, comprises the central direction of change addressed in this research. Lastly, the socio-technical transition perspective presupposes specific assumptions determining the possible research directions. These three areas are introduced separately yet in mutual coherence in this section.

1.2.1 The infrastructure sector

Infrastructure has different meanings in different contexts. In this dissertation, the infrastructure sector is understood as what is often called the civil engineering sector, or what is in the Netherlands referred to as *grond- weg- en waterbouw* (GWW). It roughly consists of the public part of the construction sector and the built environment that includes roadworks, waterworks, railways, and cables & pipes, and is often referred to as public infrastructure (World Class Maintenance, 2023). From a socio-technical perspective, infrastructure can be treated as a separate sector because of the unique yet interrelated set of actors, institutions, and physical assets (Markard, 2011). Below, three critical characteristics of the infrastructure domain that significantly shape the discourse of the transition towards a circular infrastructure sector are highlighted. These characteristics further shape the approach to studying this topic.

First, infrastructure activities take place within a highly politicized public sector, in contrast with, for example, most building construction activities. Infrastructure assets are typically procured, owned, and financed by public organizations (Caerteling et al., 2011; Dominguez et al., 2009). This public nature subjects client-contractor collaboration to procurement law, imposing strict rules to ensure transparency and a level playing field. Hence, governments draw on values distinct from the private sector (Kuitert et al., 2019; Volker, 2010). Acting as clients, governments wield considerable power in deploying governance instruments to guide the infrastructure processes, including setting specific terms for projects (Hueskes et al., 2017). These conditions, such as resources and regulations, depend strongly on political decisions. In addition, the national boundaries also create a strong interdependence between public and private actors. Consequently, infrastructure is shaped, commissioned, and maintained through a relatively fixed system of actors and institutions (Lienert et al., 2013).

In this public context, infrastructure is owned, managed, and procured by many public organizations on national, provincial, municipal, and, in some countries, regional or waterboard levels (IenW et al., 2023). Despite this major fragmentation, national clients play a prominent role. These organizations are usually the largest clients in terms of portfolio and are mostly directly connected to national politics and, hence, the long-term infrastructure investments. Moreover, these organizations strongly influence or even manage the norms and regulations in infrastructure. When addressing single client organizations in this dissertation, I use Rijkswaterstaat, the national infrastructure agency and execution body of the Ministry of Infrastructure and Water Management (IenW), as the subject of study. This organization is the Netherlands' largest infrastructure client and a dominant player in the Dutch infrastructure sector. Beyond its pivotal role within the Dutch infrastructure sector, Rijkswaterstaat is considered a frontrunner in circular infrastructure in the Netherlands, not only in terms of early-stage circular infrastructure pilots but also in knowledge development, networking, and norms and regulation (Ministry of IenW, 2020; Schut et al., 2015).

Second, infrastructure projects are typically executed as multi-actor public-private settings with predefined goals, task specifications, time/budget constraints, and interdependent team and actor relations (Harty, 2005). In these projects, conflicting interests among participants are common (Olander & Landin, 2008). The perceived conservative and risk-averse nature on the public side, sustained by high stakes and small profit margins on the private side, add to these opposing interests. Efforts to reform the sector, such as the mission on circularity, often target public-private interaction models aiming to eliminate project-oriented barriers, such as narrow scope and longitudinal fragmentation (Vrijhoef & Koskela, 2000). Examples of such models include supply chain integration (Kesidou & Sovacool, 2019), project ecologies (Hedborg & Karrbom Gustavsson, 2020), and programmatic and portfolio approaches (Pellegrinelli et al., 2015; Shehu & Akintoye, 2009). Despite these developments, none of these models have sufficiently changed the sector to effectively address the societal challenges it increasingly faces.

Third, infrastructure assets are highly unique, resource-intensive, and typically have multi-year lead times and multi-decade lifespans. These characteristics pose challenges to infrastructure management (Larsson et al., 2014). In the context of circularity, for example, these characteristics cause difficulties in measuring the benefits of innovative circular solutions to the national circularity goals, exacerbated by the lack of clarity on what circularity entails. These asset characteristics significantly affect transition dynamics, sustaining the sector's rigidity. For example, if a client decides to design a new sluice in line with circularity principles, the results of specific design choices may only materialize a decade from now, with reusability benefits occurring only after its multi-decade service life.

These characteristics make the infrastructure rigid in nature and prevent more radical types of innovation. However, the circularity transition demands fundamental changes that are not easily achieved within the current sector's configuration. This is related to the way this transition is pursued and de characteristics of circularity.

1.2.2 Steering for circular infrastructure

The CE was introduced as an integral way of using materials more effectively and efficiently to lower environmental pressure and achieve economic gains. The CE has been promoted as an alternative economic and societal model, described as "an industrial economy that is restorative by intention and design" (Ellen MacArthur Foundation, 2013, p.14). It involves a comprehensive overhaul of the production and consumption system, advocating fundamental changes that extend into the very fabric of society (Hobson & Lynch, 2016). From its early beginnings, CE has been increasingly positioned as a strategy to address multiple societal challenges. While initially aimed at reducing waste creation and material depletion, it is more and more linked with climate change considering the clear link between material use and carbon emissions (Hertwich, 2021). Recently, it has even been associated with impact categories such as biodiversity loss and soil pollution (PBL, 2023). As Lazarevic and Valve (2017, p.67) put it, "The narrated expectations for the CE are so all-encompassing that they face little critique." This can become problematic as trade-offs must be made in implementing and operationalizing the CE concept in practice.

The difficulties posed by the *all-encompassingness* stem primarily from the wicked nature of the CE. This wickedness results from the high degrees of complexity, uncertainty, and contestation of the challenges CE aims to address (Head, 2022; Rittel & Webber, 1973). Therefore, challenges such as the ones associated with circularity cannot be fully grasped and are inherently unsolvable. Instead, they can be addressed or dealt with in a way that circularity is 'better' addressed than before. For example, the contestation aspect of wickedness is visible in practice when looking at the plurality of projects and solutions launched under the CE umbrella (Coenen et al., 2022b). Instead of offering another definition of CE in the context of infrastructure, this dissertation discusses ways to address contestation through participative and reflexive approaches. Notwithstanding, key concepts that are useful to understanding the ongoing circular infrastructure discourse are introduced below.

Derived from the CE concept, *circularity* is portrayed as a quality aligning with CE discourse and usually refers to a set of principles. These principles typically comprise closing, narrowing, slowing, and regenerating resource loops to retain value and decrease environmental impact (Konietzko et al., 2020). Such principles are often outlined in frameworks such as the waste hierarchy or butterfly model (Ellen MacArthur Foundation, 2012; Potting et al., 2017). Typical solution strategies within these principles in infrastructure include the reuse of existing materials and components, lifespan extension measures, and modular asset design approaches. Appendix 1.1 provides an excerpt that discusses several circularity strategies in the context of infrastructure (Coenen et al., 2020).

Notwithstanding the myriad of interpretations of circularity and the inherent wickedness, governments across the globe have adopted the circularity concept to aim for a system that better aligns the human impacts within the planetary boundaries (Rockström et al., 2009). These initiatives exist on various scales that are important to distinguish in order to understand how circularity initiatives can be stimulated in particular contexts. The European Commission, for example, mentions construction as a priority theme in its Circular Economy Action Plan (European Commission, 2020). In the Netherlands, a comprehensive strategy was launched to render the country circular by 2050, in which infrastructure, as part of construction, occupies one of the central pillars (IenW & EZK, 2016; Transitieteam Bouw, 2018). Furthermore, this strategy was adopted and operationalized on a regional scale to fit the local contexts (e.g., Provincie Overijssel, 2020). These initiatives are often interrelated in their goals but differ in their operationalization in the local context. This plurality of scales has major implications for how certain elements of the transition can be best governed and by whom.

Recognizing the systemic nature of the change required for infrastructure, becoming circular has been positioned in the Netherlands as a *mission* with clear boundaries in scope and time (cf., Mazzucato, 2018). Such a mission can be understood as a set of specific and ambitious policy goals to transformatively address a societal challenge, involving coordinated action and collaboration among various stakeholders within a defined timeframe (Larrue, 2021). As such, it is used as a policy tool to provide direction to transformative change (Janssen et al., 2021). In our case, circular infrastructure encompasses an extensive portfolio of related projects and strategies, a broad interpretation of the stakeholder field, cross-sectoral considerations, and an inclusive governance approach. Various strategies were formulated to achieve circularity by 2050 nationally and were further specified on a sectoral scale (IenW & EZK, 2016).

These sectoral strategies, such as the "*Transitie-agenda Circulaire Bouweconomie*" (Transitieteam Bouw, 2018), will be central to the analyses in this dissertation.

Accordingly, when referred to a mission in the remainder of this dissertation, it pertains specifically to the infrastructure-related mission "Dutch circular infrastructure in 2050" (Transitieteam Bouw, 2018). This mission-oriented approach aligns with a broader trend in governance approaches where transformation, societal challenges, and missions occupy a prominent position (Kuhlmann & Rip, 2018; Schot & Steinmueller, 2018b). Due to the close association of the transition towards circular infrastructure with this predefined mission, one can speak of a *mission-oriented transition*. However, what does it mean to understand these transformative changes towards a mission as a transition?

1.2.3 Understanding circular infrastructure as a mission-oriented transition

Despite notable initiatives and examples of circular technologies and solutions in infrastructure, systemic changes are still lacking (Bours et al., 2022; Giorgi et al., 2022). A reason for this gap is the absence of a comprehensive, sector-wide view on governing and managing the implications of a circular infrastructure system. The lack of a systemic outlook is evident in the overrepresentation of circular design solutions in literature and practice, with insufficient attention to the system's underlying institutions, root barriers, and their interactions (cf., Charef et al., 2021; Hossain et al., 2020; Joensuu et al., 2020; Mhatre et al., 2021). Research on circular infrastructure has focused mainly on single technologies, practices, or barriers rather than considering those elements in mutual coherence (cf., Çimen, 2021; Kalmykova et al., 2018). While these past findings offer essential ingredients to formulate circular solution directions, they fail to consider the co-evolving nature of transitions.

To address this gap and study change from a systemic perspective, I approach the pursuit of a circular infrastructure sector from a socio-technical perspective. Specifically, this dissertation incorporates several methods to strengthen our understanding of the dynamics and mechanisms in the transition towards a circular infrastructure while providing decision-makers and practitioners with ways to move ahead. These dynamics strongly influence the possibilities and limitations of studying and governing circularity in infrastructure. Therefore, we need to understand what a transition comprises.

Transitions encompass multiple elements, such as technology, culture, and policies, that interact in a co-evolutionary way. These processes involve a broad range of actors, from academic researchers, the political arena, and industry leaders to the public sector and civil society, each with their own interests and strategies (Grin et al., 2010; Köhler et al., 2019). Moreover, transitions are long-term, open-ended, and uncertain due to the multiplicity of potential pathways and the unpredictability of external developments (Geels, 2002; Rip & Kemp, 1997). Disagreements among actors, fuelled by opposing guiding values in this strongly normative and directional process, and the normative, mission-oriented character of the circularity transition further complicate the socio-technical change (Haddad et al., 2022). To make sense of change in such socio-technical systems, it is useful to differentiate the socio-technical system from its contexts. These are conceptualized as three interrelated levels.

Three interacting levels are generally distinguished in transition studies, known as the multi-level perspective (MLP) (Geels, 2005). This perspective defines a transition as the continuous interaction between the currently dominant socio-technical system (regime) from broader developments and exogenous pressures and shocks (landscape) and the innovations potentially challenging the regime (niche). Such transitions presuppose changes in the roles and positions of actors within the system (Wittmayer et al., 2017). Here, different actors perform various activities that, together, contribute to the desired socio-technical change (Bergek, 2019). From this perspective, the transition towards a circular sector can be seen as the radical shift from a linear (i.e., non-circular) socio-technical system into a circular one through the interplay between the diverse elements and actors within the regime as well as in relation to the landscape events and niche developments. While such transitions cannot be planned or managed due to the inherent complexity and uncertainty (Stirling, 2010), they can be steered or directed. For instance, comprehensive socio-technical visions of the future can act performatively to affect and shape expectations (Konrad & Böhle, 2019).

This transition perspective has consequences for understanding the role of single actors. After all, infrastructure actors, both individually and in collaborative settings, act in distinct institutional settings to fulfil a specific role within the system (Frederiksen et al., 2021). Given the institutional pressures caused by the national circularity mission, the systemic nature of circularity, and the interdependencies between the sector's stakeholders, traditional organizational change and transformation approaches hardly apply (Bertassini et al., 2021). Instead, organizational and inter-organizational change must be considered within the broader transition dynamics (Farla et al., 2012), where the organizations, as well as the positions and power between those organizations, modify (Avelino & Wittmayer, 2016).

1.3 Objective, positioning, and justification of the research

Navigating or governing the myriad elements that interact in transitions proves challenging. To advance systemic change towards a fundamentally circular sector, academics, policymakers, and industry leaders must obtain the insights and approaches necessary to support a more effective and desirable transition. Resultingly, the objective of this dissertation is to generate the insights needed to further the transition towards a circular infrastructure. In this dissertation, I aim to contribute to several academic debates, particularly in transition studies, by operationalizing the mission concept concerning societal transitions. To serve policymakers, I aim to offer insights into the sector's transition dynamics and governance approaches that fit the nature of the mission-oriented transition towards circular infrastructure. While industry leaders, such as top management in frontrunning companies and governments, might also make use of the insights in the transition dynamics, I pursue to also provide them with ways forward regarding their strategic positioning in relation to other actors as well as the interaction between the transition and internal dynamics of organizational transformation. These insights will be acquired and approached by considering the pursuit of a circular infrastructure sector as a socio-technical transition.

In these transitions, the number, heterogeneity, and inherent unpredictability of the interacting technological, social, and institutional aspects that determine the course of developments make the socio-technical system as a whole incomprehensible (Ropohl, 1999). To still increase our understanding of circular transitions in infrastructure, we thus need to take a systemic perspective. This inevitably implies that not a particular theory or approach is central, but a domain-specific transition is taken as the research subject. Instead of zooming in on a single theoretical phenomenon, from this perspective, the complexity is embraced to do justice to the aforementioned transition characteristics (Geels, 2010). Such complexity requires frameworks to act as lenses to make sense of the world.

Geels (2022, p.11) argued that "the heuristic use of conceptual frameworks [...] in transition research is epistemologically legitimate [and] is arguably the best way of explaining socio-technical transitions in a way that does justice to their phenomenological characteristics." Such theoretical lenses help researchers to navigate through subjective interpretations that arise from their socio-historical context. Furthermore, they act as interpretive tools that guide the understanding of how various elements of socio-technical systems interact and influence transitions. This stance fits the critical realist perspective (Bhaskar & Hartwig, 2016), which I adopted throughout the dissertation.

Thus, various lenses are employed to make sense of the complexity of social constructions and socio-institutional interactions within the infrastructure domain. Instead of providing the 'ultimate truth', they facilitate a deeper understanding of specific aspects of the transition (Maxwell, 2011). To apply this diversity of lenses and frameworks, it becomes crucial to divide the research into distinct segments, each characterized by their unique methodological and theoretical fundaments. This approach allows for a comprehensive exploration of the various dimensions of the transition in order to explore ways forward in the infrastructure domain more effectively. For their strengths in embracing the complexity of the phenomena (Rotmans & Loorbach, 2009), the nuances of social dynamics throughout the research process (Zolfagharian et al., 2019), and the exploratory nature considering the uncertainties, I built the research primarily on qualitative research methods. The research focuses on this in-depth and sector-specific understanding of the circularity transition. Therefore, an in-depth single-case approach of the Dutch infrastructure sector (and related CE mission) is selected. This approach enables the examination of the socio-technical and socio-institutional dynamics from various angles.

To structure the plurality of angles, I made specific choices that capture the variety of perspectives on the transition within the case of circular infrastructure in the Netherlands and Rijkswaterstaat as the major national infrastructure client. The research will cross two central axes: time and scale. Before all else, the transition's recent past and current situation must be investigated to determine the deep-rooted challenges and barriers as well as the ongoing developments. Only afterwards can ways be explored to deal with those issues and can be proceeded to the next steps in the transition. Given the abovementioned complexities and uncertainties, a clear-cut roadmap will not offer realistic ways to address the transition challenges in the long term (Rip, 2012). Instead, I aim to offer governance tools and perspectives that enable policymakers and industry leaders to shape the transition into the future more effectively and desirably.

Because transitions are often understood in light of nested systems (Raven et al., 2012), it is crucial to understand them on multiple scales: the organizational and inter-organizational dynamics to relate the macro-level transition dynamics to the micro-level and meso-level (inter)organizational responses. Only then can approaches and tools be introduced that mobilize these individual actors from both a governance and management perspective. Since public actors are, as clients, asset owners, and policymakers, central to guiding the direction of infrastructure, the research question will be predominantly addressed from a public perspective. Nevertheless, given the interdependencies inherent to socio-technical systems, this is always executed in light of the broader sector. In doing so, the pursued outcome of this dissertation consists of approaches to govern the mission-oriented transition towards circular infrastructure on a sectoral, organizational, and interorganizational level.

Throughout the research, collaboration has been sought with other researchers to enable myself to embed the research in multiple theoretical contexts and to strengthen the overall contributions to the respective theoretical domains. This collaboration allowed me to deal with and combine multiple lenses and theoretical backgrounds to serve the domain of inquiry best, i.e., circular infrastructure. Moreover, these collaborations offered an excellent opportunity to explore and develop ideas both with and beyond the supervisory team. The collaborative nature of the studies is also a reason why I use the plural pronoun 'we' when referring to the separate studies in this dissertation. Only in the introduction and conclusion chapters is the singular first-person 'I' pronoun used when referring to my personal choices and views in the dissertation.

1.4 Research questions and approach

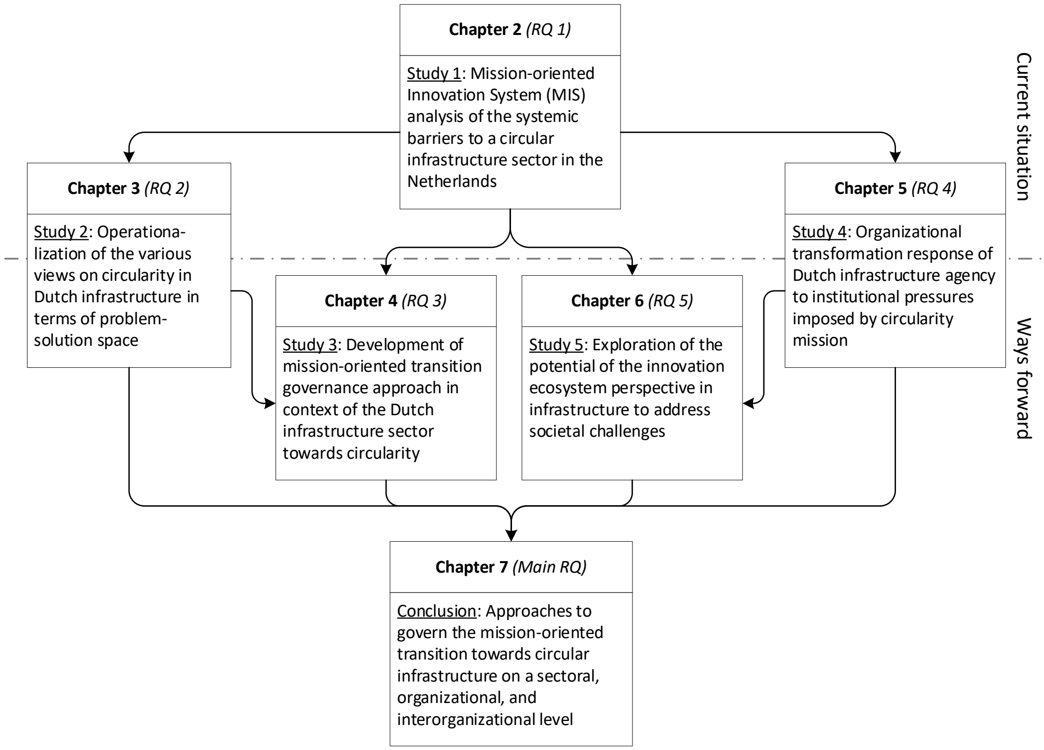
Considering the research objective stated in the previous section, the main research question that I address in this dissertation is:

How can the mission-oriented transition towards circular infrastructure be governed?

The main research question (RQ) will be addressed through five interrelated studies and related RQs. The coherence between the studies in relation to the main research question and the chapters of this dissertation is shown in Figure 1. To address the RQ, first, the understanding of the current transition dynamics and barriers must be understood. Study 1 sets the stage for the research in terms of the current state and the systemic barriers that hamper the transition circular infrastructure. Study 2 deepens the understanding of the transitions regarding one of the central root causes for the slow implementation of circularity in circularity practices – contestation of the circularity concept – and suggests approaches to deal with this. While Studies 1 and 2 question the situation as-is, Study 3 explores a way forward to govern the mission-oriented transition more effectively and robustly.

Because of the need for behavioural changes, stakeholder roles will change throughout the process. Therefore, organizational change and inter-organizational reconsiderations of interactions are needed to deal with these changing institutional contexts while maintaining operational activity. Therefore, Study 4 looks into the dynamics between conventional infrastructure management processes and circularity implementation processes within an organization that is dealing with many different institutional pressures. Next, Study 5 explores a way forward to more effectively organize cross-organizational construction works to deal with societal challenges, such as the ones related to circularity. As such this study links the operational activities of infrastructure actors to the sectoral dynamics. Together, these studies address the aim of generating the insights needed to further the transition towards a circular infrastructure. Below, these studies are individually explained in more detail.

Figure 1. Overview of the coherence between the five studies and the main objective.



To develop approaches to further the transition, first, it must be understood what the current state of the transition is and what characteristics and dynamic hamper the transition. Insights in such barriers from a socio-technical perspective require a view in which the entire system must be considered that is affected by the circularity mission. This step also requires an investigation of the aspects and dynamics in the current infrastructure system and the related circularity mission, leading to RQ 1.

RQ 1 *What are the systemic barriers and lock-ins to transitioning towards a circular infrastructure sector?*

This question is addressed in Study 1 (Chapter 2) using the Mission-oriented Innovation System (MIS) framework (Hekkert et al., 2020; Wesseling & Meijerhof, 2023). By incorporating dedicated analyses of the system's structure and ongoing dynamics, the MIS analysis allows for outlining the system's dynamics and corresponding barriers and lock-ins. Because of the long lead times of infrastructure works, the long lifespan of infrastructure assets, and the long-term materialization of circularity benefits, such analyses struggle to provide reliable predictions regarding circular output (e.g., on cross-lifecycle material reductions). Instead, to understand the current activities undertaken in practice, now and in the recent past, we identified activities related not only to specific circular innovations or technologies but much more to how the system on a sectoral level is being shaped to offer the right conditions for circular socio-technical changes towards a circular sector. Policy documents and twenty in-depth interviews served as the primary data sources to reveal ongoing processes, practices, and developments. This study resulted in the identification of three vicious cycles that hamper the adoption and upscaling of circular practices in Dutch infrastructure.

From these vicious cycles, contestation on the circularity concept in the context of infrastructure stood out as a deeply-rooted problem that prevents circular activities from being widely implemented and upscaled. In other words, there are multiple, partly conflicting 'socio-technical imaginaries' of a circular infrastructure system – next to the existing national framing of the mission. To manage this contestation, make actors aware of the diversity in interpretations, and align the interpretations of the concept better, the various ways of understanding must be revealed to enable practitioners to deal with this contestation. This is the topic of RQ 2.

RQ 2 *How is circularity in the Dutch infrastructure domain perceived by infrastructure stakeholders, and how do the various perceptions align with the formal circularity mission?*

In order to steer the transition effectively, it is crucial to understand the dominant perspectives on circular infrastructure (and how they vary) as well as their relation to the formal strategies regarding the mission. The plurality of stakeholders' ideas about both the problems circularity ought to address and the dominant solutions that should be implemented to achieve this have been conceptualized as the problem-solution space (Wanzenböck et al., 2020). This problem-solution space is used in Study 2 to map the various understandings about missions, for example, to reveal the prioritization of climate change or resource depletion as a problem and bio-based or recycled materials as a solution to circularity. However, a way of operationalizing this abstract problem space is lacking. By employing Q-methodology (Cuppen, 2012) to distil the collectively held visions of the future concerning circular construction in the Netherlands – also known as socio-technical imaginaries (Jasanoff & Kim, 2015) – we introduced an operational way of analysing the problem-solution space. By applying this operationalization to circular construction, we study the diversity of perspectives and how they differ regarding problems and solutions. We obtained initial statements on the diverse problems and solutions through twenty in-depth interviews published separately by Coenen et al. (2022a). Next, the various imaginaries were constructed based on a survey-based Q-sample with a heterogeneous set of thirty-four respondents from the Dutch infrastructure sector. We identified three significant imaginaries of circular infrastructure. Using the outcomes of the Q-methodology exercise, we identified various ways policymakers can use these insights to deal with this contestation in Study 2 (Chapter 3).

Next to the apparent contestation, the challenges that the CE mission aims to address are uncertain in their unfolding and complex due to their interdependencies. These characteristics make mission-oriented transitions wicked (Head, 2022). While missions aim to mobilize actors in a particular direction (Janssen et al., 2023), they cannot be governed in a traditional way. In other words, traditional planning and governance approaches to innovation and ‘improvement’ do not apply to mission-oriented transitions (Rosa et al., 2021). Therefore, there is a need for another way to mobilize actors and better prepare those to take circular action. Such an approach should inform decision-makers, including policymakers, on how to better govern the circularity transition in infrastructure. Therefore, Study 3, in addressing RQ 3, aims to find a way for infrastructure actors to collectively anticipate potential future transition pathways.

RQ 3 *How can infrastructure stakeholders deliberatively anticipate future developments related to the CE mission?*

By adopting principles from anticipatory, participatory, reflexive, and tentative governance, we proposed a mission governance approach to increase the social robustness, preparedness, awareness, and alignment of stakeholders and inform policy-makers. We named this approach Mission-Oriented Transition Assessment (MOTA). It was primarily developed based on theoretical traditions of Technology Assessment and Responsible Innovation. We applied MOTA in the context of circular infrastructure through an extensive workshop setting with a heterogeneous group comprising five researchers and seventeen participants from throughout the sector. A crucial part of this study was developing two plausible yet contrasting transition scenarios aligned with the pursued mission outcomes. These scenarios were designed mainly based on the knowledge developed in Study 1. The results discussed in Study 3 (Chapter 4) of this dissertation reveal how the MOTA approach helps govern the circularity mission and offers various directions for policymakers in Dutch infrastructure and beyond.

The insights from the first three studies provided an understanding of the transition's current state and future outlook on a sectoral level. To act within such a transitioning system, an organization must adopt fundamentally different processes and practices to address changing institutional demands. Organizations need insights into the transition challenges at the organizational level to determine actionable ways. A significant challenge is that such organizations must perform fundamental organizational transformations while preserving continuity and simultaneously dealing with the changing interactions with other actors and institutions, leading to RQ 4.

RQ 4 *How do infrastructure client organizations deal with the institutional pressures caused by the circularity transition?*

Given the trait to link individual and organizational practices with macro-level values and developments (Thornton & Ocasio, 1999), we adopted the concept of institutional logics to reveal how logic plurality induces tensions between the conventional organizational processes and the new ways of acting that fit the circularity discourse (Greenwood et al., 2011; Pache & Santos, 2021). An in-depth case analysis within Rijkswaterstaat infrastructure agency through twenty interviews provided the insights needed to identify the organizational responses in the various departments. These interviews included individuals from across all departments and layers of the organization. The analysis demonstrated the emergence of tensions in the infrastructure management process, highlighting conflicts between *state logic* and the circularity-aimed logics supporting processes conducive to circularity implementation. The existing logics in the literature on environmental sustainability were all value-laden and, hence, unsuited to deal with the diversity of motives by a logic's adherers. Because we observed that the individuals adhered to a more abstract pursuit for a 'better society', we introduced the *societal challenge logic* in this study.

The insights of Study 4 (Chapter 5) were collected from an organizational perspective on the institutional pressures imposed by the CE mission. Together with the findings from Chapters 2 and 4, this stresses the need for fundamentally new practices, processes, and ways infrastructure stakeholders act and interact. Notably, the sector's public and project-based natures prevent long-term collaboration, obstructing actors from developing future-oriented relationships. Since missions address societal challenges that reach far behind the horizon of individual projects, other ways of collaboration and innovation are crucial to taking fundamental steps towards circularity. One of the approaches for actors to innovate for long-term societal solutions that contribute to societal missions, such as circularity, is the *innovation ecosystem* (Konietzko et al., 2020). We explore this perspective in the infrastructure context in Study 5. An innovation ecosystem is generally understood as a collaborative network of actors fostering the development and growth of new ideas and technologies. In other sectors, such as the tech or automobile industries, innovation ecosystems are well-established for facilitating complex and long-term innovations (Adner, 2016). While the innovation system approach might work in these other domains, the potential benefits and limitations for the infrastructure sector are unclear, which leads to RQ5.

RQ 5 *How can the innovation ecosystem concept facilitate collaborations to innovate for challenges beyond the project context?*

In Study 5 (Chapter 6), we studied the potential and limitations of innovation ecosystems in the context of innovative infrastructure projects based on the central characteristics of innovation ecosystems literature. Using these characteristics, we looked at five empirical collaborative settings with an innovation-oriented character and project-transcending innovation goals in the infrastructure practice to explore how and to what extent these initiatives could be understood as innovation ecosystems and how they could benefit from applying innovation ecosystem traits. Four of these cases aimed explicitly at implementing circular solutions in infrastructure and the fifth case regarded circularity as an implicit outcome. Studying these cases allowed us to foreshadow the potential and limitations of innovation ecosystems as a framework for project-transcending collaboration and innovation in the infrastructure domain. This resulted in several approaches in which the limitations of projects to address long-term objectives, such as circularity, could be addressed effectively. Despite the potential for adopting an innovation ecosystem perspective to offer the conditions to deal with societal challenges, a key finding was the notoriously difficult need for cultural and behavioural changes throughout the sector.

1.5 Structure of dissertation

The overview of the dissertation's chapters is summarized in Table 1. The main body of this dissertation, starting subsequent to this introductory chapter, is composed of five journal articles, each representing a chapter that addresses a separate research question. Despite being executed as separate studies with different theoretical underpinnings, the studies are building upon each other, together addressing the overarching main research question (Figure 1). Each paper is integrally inserted as a chapter. However, slight language and style adaptations, such as abbreviations, actor names, and UK/US English, are applied to safeguard consistency throughout the dissertation. Given the collaborative nature of the research approach, a separate column is included in the figure to offer transparency on the contributions of the co-authors of each chapter.

After the five chapters representing separate studies, the dissertation ends with a concluding chapter in which the action perspectives to serve decision-makers are explicitly linked to the scales and timeframes. Beyond addressing the RQs, I reflect upon the implications for both theory and practice beyond the single dissertation's chapters in this final chapter. Moreover, the concluding chapter reflects on the limitations and outlook for future research.

The domain of circular infrastructure being the constant, the research in this dissertation is executed using multiple theoretical and conceptual lenses for the separate studies. Considering the main research objective, I believe this is a strength of the overall research approach, as it allows for shedding multiple lights on the challenges of the respective transition. Nevertheless, reading the dissertation cover to cover might feel theoretically and methodologically perplexing. Therefore, I recommend carefully reading the chapters' theoretical and methodological sections before reviewing the results and conclusions.

Table 1. Overview of the dissertation, author contributions, and related publications.

Ch. #	*Chapter title*	*Research question (RQ)*	*Author contribution**	*Published as*
1	Introduction.		T.B.J. Coenen (*Co, MWD, RE*) L. Volker (*RE*) K. Visscher (*RE*)	Only as a chapter in this dissertation.
2	A systemic perspective on transition barriers to a circular infrastructure sector.	(Study 1) What are the systemic barriers and lock-ins to transitioning towards a circular infrastructure sector?	T.B.J. Coenen (*Co, Me, FA, ID, MWD, RE*) K. Visscher (*Co, CWD RE*) L. Volker (*Co, CWD, RE*)	Coenen, T. B. J., Visscher, K., & Volker, L. (2023). A systemic perspective on transition barriers to a circular infrastructure sector. Construction Management and Economics, 41(1), 22–43.
3	Operationalizin g contested problem-solution spaces: The case of Dutch circular construction.	(Study 2) How is circularity in the Dutch infrastructure domain perceived by infrastructure stakeholders, and how do the various perceptions align with the formal circularity mission?	M.J. Wiarda (*Co, Me, FA, MWD, RE*) T.B.J. Coenen (*Co, ID, FA, MWD, RE*) N. Doorn (*Co, RE*)	Wiarda, M., Coenen, T. B. J., & Doorn, N. (2023). Operationalizing contested problem-solution spaces: The case of Dutch circular construction. Environmental Innovation and Societal Transitions, 48(November 2022), 100752.
4	Mission-Oriented Innovation Systems: The case of circular infrastructure.	(Study 3) How can infrastructure stakeholders deliberatively anticipate future developments related to the CE mission?	T.B.J. Coenen (*Co, Me, FA, ID, MWD, RE*) M.J. Wiarda (*Co, ID, MWD, RE*) K. Visscher (*Co, RE, ID*) C.R. Penna (*Co, CWD, RE*) L. Volker (*RE, ID*)	Under review.

Ch. #	*Chapter title*	*Research question (RQ)*	*Author contribution**	*Published as*
5	Navigating institutional plurality in pursuit of a circular economy.	(Study 4) How do infrastructure client organizations deal with the institutional pressures caused by the circularity transition?	T.B.J. Coenen (*Co, Me, FA, ID, MWD, RE*) N.I. Frederiksen (*Co, MWD, RE*) L. Volker (*Co, RE*) K. Visscher (*RE*)	Under review.
6	Collaboration and innovation beyond project boundaries.	(Study 5) How can the innovation ecosystem concept facilitate collaborations to innovate for challenges beyond the project context?	L. Vosman (*Co, Me, FA, ID, MWD, RE*) T.B.J. Coenen (*Co, Me, FA, ID, MWD, RE*) L. Volker (*Co, CWD, RE*) K. Visscher (*Co, RE*)	Vosman, L., Coenen, T. B. J., Volker, L., & Visscher, K. (2023). Collaboration and innovation beyond project boundaries: exploring the potential of an ecosystem perspective in the infrastructure sector. Construction Management and Economics, 41(6), 457–474.
7	Discussion and conclusions.	(Main RQ) How can the mission-oriented transition towards circular infrastructure be governed?	T.B.J. Coenen (*Co, MWD, RE*) L. Volker (*RE*) K. Visscher (*RE*)	Only as a chapter in this dissertation.

**Co = Conceptualization; Me = Methodology; FA = Formal analysis; ID = Investigation and data collection; MWD = Main writing original draft; CWD = Co-writing original draft; RE = Review and editing.*

chapter 2

a systemic perspective on transition barriers to a circular infrastructure sector

Abstract: Due to the large use of resources and waste generation, the transition to a circular economy (CE) has become a major sustainability-related topic in construction. Intentions to achieve circularity are shared widely, but developments are slow in practice. This study identifies systemic barriers to the circularity transition from a socio-technical, systemic perspective. We used the Mission-oriented Innovation System (MIS) framework to provide insights into the problems and potential solutions underlying the CE mission, the structure of the system and the system dynamics. Based on the analysis of a wide range of policy documents and twenty in-depth interviews with stakeholders in the Dutch infrastructure sector, three vicious cycles were identified that form persistent barriers to the transition: (1) the *circularity contestation cycle* given the contested nature of the CE mission; (2) the *knowledge diffusion cycle* given the need to adopt and diffuse knowledge; and (3) the *innovation cycle* when it comes to procuring and upscaling circular innovations. These barriers all relate to processual, organizational and institutional challenges rather than to technological ones. This indicates that construction managers, policymakers and researchers in the field of infrastructure circularity should shift their focus from specific circular solutions to creating appropriate conditions for changing current and introducing novel processes that facilitate circular ways of doing things.

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Coenen, T.B.J., Visscher, K., & Volker, L. (2021). Appraising the mission-oriented innovation system framework in practice: The transition towards a circular infrastructure sector. Eu-SPRI Early Career Conference, Paris, 2021.

2.1 Introduction

Due to the large use of resources and waste generation in construction, the transition to a circular economy (CE) has become a major sustainability-related topic (Benachio et al., 2020; Joensuu et al., 2020). Unfortunately, in practice, developments lag the widely shared intentions and strategies for achieving circularity, despite the growing body of literature on CE in the built environment (Mhatre et al., 2021). Much of this literature targets specific strategies, technological solutions or frameworks that should be applied, such as novel design or reuse strategies (Charef et al., 2021). Further, the majority of the CE literature focuses on the private rather than public sectors, such as infrastructure, and this has major implications for implementation (Klein, et al., 2022). However, becoming circular as an industry requires not only new technologies but also socio-technical changes, including context-specific reconsideration of relationships, institutions and practices (Singh et al., 2021). As such, socio-technical change towards an inherently more sustainable system is needed, a process which is referred to as a sustainability transition (Köhler et al., 2019).

Despite this general recognition, the barriers to introducing these changes in practice just seem to be too high within the current industry for a smooth transition to take place. When considering systemic change, most construction and project management scholars look at specific actors, projects, institutions, indicators, tools, mechanisms or practices rather than the sector at large. Gluch and Svensson (2018), for instance, explained changing practices as requiring intertwined multilevel actions by practitioners. Others took a more systemic view regarding sectoral change but focussed on a specific (technological) solution (Toppinen et al., 2019). Salmi *et al.* (2022) considered the wider sustainability transition in construction by focusing on the role of municipalities within the wide landscape of actors. In a similar vein, a systemic view was adopted to understand the role of narratives as temporal discourses to guide and shape innovation (Ninan et al., 2022). While Leiringer *et al.* (2022) addressed the systemic level, leaving room for many solutions to become circular, their scope was unfortunately limited to the role of assessment methods. Although individual solutions and strategies are important ingredients for a successful transition, understanding these is not enough to inform policymakers of the actual barriers to comprehensive system change. We therefore aim to identify the root causes of a smooth transition towards a CE at the industry level, referred to as systemic barriers.

From a policy perspective, socio-technical transitions are increasingly directed towards shared societal challenges synthesized in missions (Schot & Steinmueller, 2018a). Such missions are formulated in sectoral, national or even supra-national agreements on, for example, climate change, socioeconomic inequality or insecurity (Mazzucato, 2018a). These missions can be found on supra-national levels, such as the United Nation's Sustainable Development Goals (SDGs), but also on national and regional levels, and even within organizations and often include open-ended discourses and shared long-term goals (Janssen et al., 2021; Kuhlmann & Rip, 2018). Mission-oriented innovation policies are considered instrumental in shifting transitions towards a desired direction (Schot & Steinmueller, 2018a), since such policies "[provide] directionality in supporting the process towards converging problem-solution constellations" (Wanzenböck et al., 2020, p.475).

The purpose of this chapter is to reveal the systemic barriers to transitioning towards a CE in the infrastructure sector by analysing a construction sector in transition and seeking an understanding of the circularity transition in construction that goes beyond single changes and solutions. Specifically, we study the Dutch infrastructure sector, which is considered a frontrunner in CE policy (Giorgi et al., 2022), to contribute to knowledge building on this topic in the field of construction management.

To address the co-evolutionary and non-linear dynamics that are inherent in transitions (Köhler et al., 2019), we employ the Mission-oriented Innovation System (MIS) framework (Hekkert et al., 2020; Wesseling & Meijerhof, 2023). This framework takes a systemic and directional view concerning transitions, rather than looking at specific solutions or practical problems that negatively influence the pace and direction of transformative processes (Wieczorek & Hekkert, 2012). We aim to determine how mission-oriented innovation policies can accelerate specific mission achievements since clarity is needed on the structure and dynamics of the socio-technical system including its actors and activities in which the transition takes place (Hekkert et al., 2007).

The remainder of this chapter is structured as follows. First, in Section 2.2, the general transition concepts are introduced to inform the subsequent MIS framework in Section 2.3 that we use to study the transition. This is followed by a discussion of the research approach and the empirical results in Sections 2.4 and 2.5 respectively. The chapter continues with a description of the barriers in Section 2.6 and a discussion their implications in Section 2.7, before drawing conclusions and providing recommendations in Section 2.8.

2.2 Understanding transformations of socio-technical systems

Transitions are generally understood as transformations of socio-technical systems (Grin et al., 2010). Such systems, which can be delineated, possibly spatially or sectorally, consist of many elements that co-evolve and change the system. This shift is propelled through an interplay that involves many actors and institutions (Geels, 2004). Transitions embody a transformation or replacement of socio-technical regimes. These regimes refer to a "semi-coherent set of rules that orient and coordinate the activities of the [actor] groups that reproduce the various elements of [the system]" (Geels 2011, p.27). Change processes are generally assumed to be contested, inherently uncertain and multi-decade in duration (Köhler et al., 2019). In addition, societal challenges and specific missions, such as the quest for a CE, add a normative and directional component to this change, often approached from a public policy perspective (e.g., Janssen *et al.* 2021). Beyond trying to fix market failures, governments increasingly intervene to direct change in a societally desirable direction – i.e. a mission (Mazzucato et al., 2020).

When studying a transition, it is generally assumed that the socio-technical structures exist in an independent but layered way and are not directly observable (Geels, 2022). Therefore, although mediated by individuals, knowledge can only be captured by studying socio-institutional causal mechanisms through a wide range of potential frameworks and methods. To reveal systemic barriers to the transition towards a CE in the Dutch infrastructure sector, it is therefore helpful to adopt an analytical framework that enables us to link observable developments in the sector to explanatory mechanisms.

We use the concept of Innovation Systems as explained by Carlsson et al. (2002) to describe the constellation of components, relationships and attributes involved in the development of innovation. Depending on the scope of the change or innovation, and the boundaries placed around the system, conceptualizations vary and can be in the form of National Innovation Systems, Sectoral Innovation Systems or Technological Innovation Systems (TIS) (Souzanchi Kashani & Roshani, 2019). Traditionally, these Innovation Systems have been aimed at helping policymakers stimulate innovativeness for economic growth in a particular context. Over the past decade, the TIS concept, in particular, has developed into a framework for policy-making, addressing sustainability transitions around the development of specific (sets of) technologies embedded in socio-technical systems (Köhler et al., 2019). In particular, a system functions approach has become a key feature in explaining the development, diffusion and utilization of changes and innovations (Bergek, 2019). The rationale for these system functions is that the lack of a positive presence and alignment of functions is indicative of system weaknesses and reveals opportunities for policy improvement and intervention (Hekkert & Negro, 2009). Examples of such empirical studies in the construction industry include the sustainability transition of sustainable concrete in the Netherlands (Wesseling & Van der Vooren, 2017) and the introduction of wood in multi-storage buildings in Finland (Toivonen et al., 2021).

Grounded in the TIS framework as well as responding to the call to shift innovation policy from economic growth towards stimulating innovation towards a specific societal mission (Kattel & Mazzucato, 2018; Kuhlmann & Rip, 2018), Hekkert et al. (2020) proposed the Mission-oriented Innovation System (MIS) framework. Here, the MIS places the mission, such as the development of a CE or a zero-carbon society, at the centre of the system analysis.

2.3 The mission-oriented innovation systems (MIS) framework

The Mission-oriented Innovation System (MIS) framework is defined as “the network of agents and set of institutions that contribute to the development and diffusion of innovative solutions with the aim to define, pursue and complete a societal mission” (Hekkert *et al.,* 2020, p.77). It facilitates the analysis of innovation and change-delineated systems concerning predefined missions. Eventually, the structure and functioning of the predefined MIS provide the insights needed to determine the barriers to effective mission attainment. The MIS framework consists of four major parts that need to be determined (Wesseling & Meijerhof, 2023). The first part is the problem-solution space. This concerns the definition of, and dynamics between, the societal challenges that the mission aims to address (e.g. climate change) and the potential solutions to address these challenges (e.g. wind energy). It focuses on the level of convergence between the framings of the societal problems underlying the mission and the variety and prioritization of solution pathways (Wanzenböck et al., 2020).

The second part pertains to the composition and rules of the system. This includes the system elements, their relationships, and the boundaries of the MIS. These can be derived from a description of the involved actors, networks and institutions that give the system its particular and unique characteristics. As such, this provides the boundary conditions for the workings of the system. Moreover, an analysis of the structure addresses the presence and structure of one or more *mission arenas* within the wider MIS. These are defined by Wesseling & Meijerhof (2023, p.3) as “[spaces of] actors that are engaged in the highly political and often heavily contested process of mission governance”. Depending on the mission, arenas can be industry networks, collections of frontrunners or formal working groups that aim to direct the mission.

The third part consists of the innovation-enabling or innovation-preventing activities and processes within the system in terms of the mission. This system functioning is determined based on theory-derived but empirically validated key system functions (Bergek, 2019). Largely based on TIS conceptualizations and empirical case studies (Bergek *et al.*, 2008; Hekkert and Negro, 2009), the MIS functions are defined as abstract categories of (clusters of) activities and subprocesses of the overall innovation processes that provide insights into the dynamics and potential patterns of change and innovation concerning the development of the innovation system (Hekkert et al., 2007). Although the extent to which the system functions need to be present or aligned depends on the particular system studied, they have explanatory power concerning transformational failures and play a crucial role in identifying systemic barriers (Raven & Walrave, 2020). In addition, the performance of functions can be causal. For example, a lack of legitimacy for a specific mission (e.g. increasing biodiversity) might lead to a lack of resources (e.g. no subsidy schemes), which might lead to a lack of entrepreneurial activities (e.g. only a few pilot projects). The resulting list of MIS functions adapted from Wesseling and Meijerhof (2023) is shown in Table 2.

The knowledge of the problems and solutions that the MIS addresses, the structural characteristics of the MIS, and the activities and developments that take place in the MIS that influence mission attainment provide an understanding of the MIS. Together, these three parts enable the identification of barriers (the fourth part) by revealing causes of, and causalities between, the underperforming or misaligned functions based on the events and activities that are linked to the functions. The resulting causal chains can result in vicious and virtuous cycles (Suurs, 2009). These causalities provide insights into the locked-in dynamics that are valuable in determining interventions that can remove barriers and guide and stimulate a transition – in our case the transition to a circular infrastructure sector.

2.4 Research approach

In this section, we first introduce the case study of the transition towards a circular infrastructure sector in the Netherlands. Second, the data sources and collection methods are discussed and, third, we explain how these data were analysed.

2.4.1 Case selection, characteristics and boundaries

We apply the MIS framework to the Dutch infrastructure sector since this is considered a frontrunner in CE policy (Giorgi et al., 2022). For this research, boundaries were placed around Dutch infrastructure works commissioned by public bodies only. These include road infrastructure, railway infrastructure and waterways, and all supportive assets, such as bridges, dams, sluices and tunnels. Energy infrastructure, telecommunication infrastructure and the cable and pipe subsectors were not part of this analysis.

Table 2. List of MIS functions (adapted from Wesseling & Meijerhof, 2023).

Code	*Function*	*Description*
F1	Entrepreneurial activities	Activities, initiatives, experiments, pilot projects, market introductions and novel business models regarding (clusters of) novel solutions related to the mission.
F2	Knowledge development	Creating knowledge of the problems and solutions "by research" and "by doing", including forecast studies, laboratory work, field studies, working groups and strategic studies.
F3	Knowledge diffusion	Dissemination and adoption of knowledge regarding the problems and solutions through media, stakeholder meetings, knowledge networks, governance structures, publications and interaction.
F4		
F4a	Problem directionality	Formulation and guidance of the societal problem(s) concerning the mission and their priority and interaction concerning other societal problems and missions.
F4b	Solution directionality	The efforts made to provide direction towards the mission goals in terms of (clusters of and coordination between) potential solutions and their priorities.
F4c	Reflexive governance	Monitoring, evaluation, active learning, impact assessment, securing knowledge and anticipation of progress to provide input for guidance and governance concerning the mission attainment.
F5	Market creation and destabilisation	Creation of conditions such that innovative solutions can develop and compete with existing practices through, for example, creating "arenas", and pricing mechanisms, as well as phasing out and destabilizing undesirable markets concerning the mission.
F6	Resource (re-)allocation	Mobilization of financial, human and material resources to enable other system functions and withdrawal of resources that support unwanted activities concerning the mission.
F7	Creation and withdrawal of legitimacy	Creating and eliminating legitimacy and social acceptance for the solutions and problems respectively and in favour of the mission through raising awareness, stakeholder engagement, lobbying, standardization, championing etc.

Infrastructure sectors have several typical characteristics that affect which data can be collected and how. First, it is a public sector with a highly politicized context. This means that the assets are generally purchased, owned and financed by public organizations (Dominguez et al., 2009). Further, client-contractor relations are subject to public procurement law, which puts strict rules on contracting to guarantee transparency and a level playing field (Volker, 2010). Here, the government, as a client, has considerable power in setting the terms for specific projects and in deploying specific governance instruments (Hueskes et al., 2017). Nevertheless, infrastructure is designed, commissioned and maintained through a rather fixed system of actors and institutions (Lienert et al., 2013).

Second, infrastructure assets are highly unique, resource intensive and often have multi-year lead times and multi-decade lifespans. This leads to challenges in planning, management and governance. Moreover, it is difficult to measure circularity benefits in the infrastructure sector due to these long asset lifespans and lack of clarity as to what circularity is in this context (Coenen et al. 2021a). Third, infrastructure works are usually executed as multi-actor public-private projects with strict predefined goals and task specifications, time/budget constraints and interdependent team and actor relations (Harty, 2005). In these projects, participants traditionally have conflicting interests (Olander & Landin, 2008). Overall, the reputation of the sector is a conservative and risk-averse one, sustained by the small profit margins.

2.4.2 Data collection

For the case study, we collected data from multiple sources to reveal insights into the first three components of the MIS framework. In terms of the problem-solution analysis, we studied the range of problems and solutions as reflected by the mission. These were collected from policy documents and then complemented and validated by interviews. For the structural analysis, we established an overview of the sector in terms of actors and institutions. Here, too, policy documents served as the primary data source. In addition, academic literature was used to understand the particularities of the sector and interviews were then carried out to complement and validate the findings. To identify the presence and relationships between the MIS functions (Table 2), we needed to understand the developments in the sector as experienced by practitioners. Here, we carried out in-depth interviews rather than study policy documents as the primary source on the basis that such documents tend to reflect what used to happen or ought to happen rather than what currently happens in practice.

Thirteen policy documents were studied to define the mission, mission arenas and predefined boundaries of the Dutch infrastructure sector (see

Appendix 2.1). This set contained documents produced between 2015 and 2021 by central and regional governments and industry networks that specifically addressed circularity goals, measures and strategies for infrastructure. These documents were collected through an internet search. Here, we primarily made use of the formal website of the "circular construction economy" that was launched by the Dutch Government.

The interviewees were selected using a purposive sampling strategy (Campbell et al., 2020), aiming to include a variety of perspectives on the transition and the different actor types as categorized by Kuhlmann and Arnold (2001). These categories included demand (public clients), industrial system (contractors and suppliers), intermediary organizations (network organizations, advisories and thematic experts), education and research (public and private research organizations), resource infrastructure (financers) and political system (policymakers). The results from the analysis of the policy documents were used to specify the interview questions that were largely deduced from the system functions of the MIS framework (Table 2) and to tailor these to the infrastructure context.

In total, twenty people were interviewed in two sets of interviews. First, we conducted ten in-depth semi-structured interviews of approximately ninety minutes each. The identified MIS functions were used as a basis to acquire a general overview of the performance and dynamics of the MIS in practice. These interviews helped to generate a systemic view by tracing developments in an explorative way. In line with the interpretive genre in interview studies (Langley & Meziani, 2020), we focused on the differing perspectives and backgrounds of the interviewees. Hence, this first set of interviews produced an overview of the unclarities, ambiguities and contested subjects. The second set of interviews was executed following a more structured approach that focused on clarifying specific unclarities. Saturation was reached after ten of these structured interviews (see Appendix 2.2 for the full anonymized list). These were transcribed verbatim, resulting in twenty documents of 7,000-13,000 words each.

2.4.3 Data analysis

We analysed the policy documents to create a narrative on the development of a CE since 2015, and to determine the problem and solution spaces and their interaction. Statements from the interviews were used to complement and validate this narrative. Furthermore, the documents were analysed on the actor and actor group level to establish an overview of the mission arenas and structural barriers to the transition. In addition, we analysed professional and scientific literature to create a comprehensive overview of the system, including specifics of the infrastructure sector that affect developments towards mission attainment, such as its project-based nature, dependence on procurement law and long asset lifespans.

The Atlas.ti software tool was used to link the interview data to system functions (Table 2). For example, when an interviewee mentioned the financing of a circular pilot, it was labelled under function 6 (resource mobilization) and when an interviewee explained the consequences of the procurement process for the ability to develop circular solutions it was placed under function 5 (market formation). Next, all the comments regarding a particular function were summarized for each interviewee. We inserted these quotes in a large matrix with the interviewees on one axis and the MIS functions on the other, followed by a cross-interviewee analysis for each function, in which each referral to another function or structural characteristic was noted separately. This was first done for the first ten interviews and later complemented with the latter ten. Finally, we summarized the functions in qualitative terms based on the matrix to draw conclusions on their performance.

By studying the functional relationships mentioned by interviewees and by searching for explanations for underperforming functions in the interview transcripts and policy documents, causal links between functional and structural elements that hamper the transition were identified. These were assembled in an elaborate causal diagram in which specific reasons were linked to specific functional and structural elements. The resulting diagram was discussed with professionals from Rijkswaterstaat. Based on this validation with practice, elements with similar causations were clustered to simplify the diagram. This enabled the identification of three vicious cycles that can be understood as looping chains of cumulative causation (Suurs, 2009) that we labelled: (1) the *circularity contestation cycle*; (2) the *knowledge diffusion cycle*; and (3) the *innovation cycle*.

First, we discuss the problem-solution analysis, structural analysis and functional analysis from the MIS framework, followed by describing the barriers and vicious cycles that were identified within the Dutch infrastructure sector. The results related to the first three framework components are described in the Section 2.5, and the final systemic barriers in the fourth part are discussed in the Section 2.6.

2.5 Results and analysis

2.5.1 Problem-solution analysis

The Dutch government set a mission to be fully circular in 2050, but it is experiencing difficulties in the implementation of circular innovations and practices for achieving this mission (Hanemaaijer et al., 2020). Since 2014, circularity gained traction as a holistic means to reduce environmental impact and sustain a healthy economy. It ever since developed into one of the dominant concepts in the field of environmental sustainability (Goyal et al., 2021). Generally, the interpretation of the circularity definition is linked to closing resource loops in order to minimize resource depletion and waste creation in all industries (Kirchherr et al., 2017).

Nevertheless, the focus on technological solutions and economic gains, rather than the resulting environmental impact, has also been one of its main criticisms (Corvellec et al., 2022). While it gained popularity, the diversity of interpretations also increased, leading to CE being an essentially contested concept (Blomsma & Brennan, 2017; Korhonen et al., 2018). The differing interpretations are not only limited to the pluralistic perspectives of scholars, but also include varying meanings in particular geographic, sectoral, technological and socio-economic contexts (Calisto Friant et al., 2020), and have changed through time.

Nevertheless, many public organizations have incorporated circularity in strategies and policies. Here, circularity has often become a goal in itself with time-bound targets in terms of waste reduction, reduction of virgin material uses and reduction of carbon emissions. Despite being presented as a mission in itself, in many documents, circularity had been introduced as a means to address societal challenges on all governance levels, not just resource scarcity and waste generation but also wider issues, such as carbon emissions and loss of biodiversity. In the next sections, the mission development and current problem-solution space are discussed in greater depth.

The origins and goals of the CE mission in Dutch infrastructure

For the Dutch infrastructure sector, according to a policy officer, “the step towards formal CE policy was taken rather radically”. It was connected to previous and parallel missions and agreements. Largely grounded in the national strategy *Nederland circulair in 2050* [The Netherlands circular in 2050], the Resource Agreement stated that the infrastructure sector should procure 100% circularly in 2023, reduce its use of virgin resources by 50% in 2030, *work circularly* while reducing its CO_2 emissions by 49% in 2030 and *be fully circular* in 2050. The resulting transition agendas published in 2018 formed the starting point for the formal sectoral transition.

Substantiation and execution of the national mission for infrastructure take place from 2018 onward, aside from their initiatives, largely delegated to Rijkswaterstaat [Dutch Directorate-General for Public Works and Water Management]. The goals and strategies were adopted in agreements by other public bodies such as municipalities, provinces and waterboards. Substantiation and operationalization of the strategies differed between these decentral government bodies and appear to have been poorly aligned and coordinated. The Unie van Waterschappen [national waterboard platform] was an exception. As one representative mentioned, “we, as 21 waterboards, find it essential to exude a shared ambition”; a view that differs from the more politicized and individualistic disposition of municipalities and provinces.

Problem space

Despite the clear goals in policy documents, interviews revealed contestation about the problem space in practice. This contestation centred around the societal challenges that the mission addressed, to what extent there was consensus on these challenges, and how the mission related to other missions and challenges – particularly concerning *sustainability*. In addition, some interviewees presented a definition of circularity in terms of solutions, or even in terms of measurement criteria, rather than in terms of problems. Although considering circularity as a goal might increase the actionability of the concept, it runs the risk of developing solutions that address no essential problems. Also, there appeared to be no consensus on potential feasibility. Moreover, the meaning of circularity seems to be an evolving construct and the question is how useful it is to capture such a fluid concept in a fixed conceptualization. As one interviewee put it, “if we keep adapting the definition of what a 100% CE means, we will eventually get there, but if we stubbornly hold on to the current definition, we won’t”.

Several interviewees stressed the importance of distinguishing *circular economy in general* from *circular construction* or *circular infrastructure*. The former interpretation relates to reforming society at large towards a closed-loop system, whereas the latter is aimed at more concrete resource-related issues in the construction process, often addressing specific issues of resource depletion. Most interviewees who did not distinguish between the two seemed to have interpreted circularity as the latter. Nevertheless, the operationalization of both interpretations through circular solutions was strongly subjected to contestation.

Solution space

Specific solutions were barely and only specified in the policy reports in abstract terms. However, when analysing the interviewees’ interpretations of the solution space, operationalizations of circular solution pathways appeared on three levels (Table 3). First, there was the level for actual (technological) solutions, such as modular design or bio-based materials. Second, there was the level of circularity design, construction and operation strategies. This includes the waste hierarchy, in which various *Rs* are defined to be circular to a certain extent (e.g., Potting et al., 2017). This waste hierarchy could also be found in several policy documents. Third, there were solution directions aimed at the conditions necessary for a circular system, such as data strategies, measurement tools or procurement strategies to facilitate circular decision-making during asset lifecycles. The overall Dutch strategy in infrastructure seems to be focusing on this third level, particularly with respect to procurement as a tool to stimulate circular alternatives.

Table 3. Circular solutions in the infrastructure sector exist on three levels.

Level of solution	*Description and examples*
1. Technological solutions	Circular solutions in terms of material use, design strategies or other technological changes or innovations. Well-known examples are bio-based materials and modular design.
2. Solutions as abstract strategies	Circular solutions in terms of conceptual strategies and principles, e.g., refuse, reuse and recycle. The most prominently applied way is the waste hierarchy, which is often operationalized in the R-ladder (varying from 3 to 10 Rs).
3. Solutions on conditions for circularity	Circular solutions in terms of conditions for facilitating the first two categories, are often aimed at processual, institutional and organizational changes. Well-known examples are circular data management strategies and circular business models.

Solutions on the third level appear to be rapidly converging as there are, at least on paper, numerous networking activities. However, solutions for the first two levels are still highly contested throughout the sector. The first level is still divergent, indicated by the high level of experimentation and low level of uniformity, which, according to some interviewees, fits the current early phase of the transition. In line with several other respondents, a public manager observed that "rather than a sustainability issue, circularity is an asset management issue". In a similar vein, several interviewees stressed that the circularity transition is an organizational challenge, rather than an innovation challenge.

Specific solutions are generally developed by market parties to address public tenders. These solutions are eventually determined by the public clients who either develop, purchase or collaborate on certain solutions. As such, the public clients' procurement power strengthens the top-down ability to steer the formal problem direction. This resonates with Jones (2018) who urged for an intelligent combination of top-down steering and bottom-up action concerning a widely-interpreted sustainable built environment. However, an interviewee also pointed out that, “often, not only the [circular] solution, but also the [level of] circularity ambition is procured”, indicating a lack of central (top-down) steering and coordination from a client’s perspective. This is problematic because by only addressing that “something circular” is desired and not the degree and boundaries of the conceptualization, it is nearly impossible to compare and reward particular circular ideas within conventional procurement processes.

Problem-solution interaction

The problem interpretation of the interviewees in terms of solutions indicates that the directions and interpretations of the solutions result, not only from the problem interpretation but also from the operationalization and direction of the problem that are influenced by the solution. Similarly, the question as to whether circularity is a goal in itself, or a means, has blurred over time, especially in project contexts. A consultant even explained that because of problem and solution contestation “I try to avoid terms like circularity and sustainability and instead talk about the underlying problems and how we can solve them”. This is in line with the findings on the innovation trajectory of the Circular Viaduct in which the first reusable and modular viaduct was developed as discussed in the introduction chapter. This case affected the Dutch understanding of circularity as a concept in terms of circular design principles.

2.5.2 Structural analysis

Structure of the Dutch infrastructure MIS

The barriers to a circular infrastructure sector depend on the structure of the studied system and its context. Dutch infrastructure works rely on the involvement of various public bodies which are coordinated from various ministries and regional governments. Furthermore, the sector encompasses multiple subsectors, both horizontally (e.g., waterways, roads, railways) and vertically down the supply chain (e.g., bridge elements, concrete production) and has no clearly delineated boundaries. Both because of the distinctive governance bodies and the many separate subsectors, the Dutch infrastructure sector is generally considered fragmented by nature. In addition, the actors are highly interdependent, given the regional nature of the construction market and the small size of the Netherlands. While the clients guide the direction with their purchasing power, eventually, the market parties introduce innovations. This results in tense and opposing relations and values across the whole sector (Kuitert et al., 2019).

The Dutch infrastructure sector consisted in 2019 of over 1,100 contractors, where only 34 companies have over 100 employees (EIB, 2021). The demand side of the sector involves only a few large public clients (national and regional bodies) but a few hundred smaller ones (mostly municipalities). In addition to the clients and contractors, the sector comprises a large number and variety of, e.g., suppliers, consultancy and engineering firms, knowledge institutions and financers, as well as societal pressure groups and lobby groups that influence the direction and pace of transition in the sector and are generally considered to have a lot of power. Nevertheless, there is considerable variation in the intensity and impact of the actors involved in the transition process and circularity at large. Within the many subsectors, by far the most turnover was generated from road construction, followed at some distance by concrete civil engineering structures (*ibid.*).

Next to these actor constellations, the Dutch infrastructure sector has some specific features that potentially affect the circularity transition. First, from a political perspective, the past decades have been dominated by a neoliberal system in which the New Public Management has become a central governance paradigm (Kuitert, 2021). Here, the market has become more dominant in determining direction at the cost of top-down public steering in which responsibilities have been strongly shifted towards market parties (known as “markt, tenzij” [market, unless]). Strengthened by the breach of confidence resulting from the “Bouwfraude” [major collusion scheme of market parties in the 1990s and early 2000s], the main task of the government has become to offer the conditions for the market to exploit its full competitive potential while risks are also allocated to the market. Due to the fierce competition between the market parties, the profit margins are generally low, while the stakes and risks taken are high. However, in the past few years, public-private relations have slowly shifted towards a more collaborative approach towards finding solutions and executing infrastructure works as a response to the structural time and budget overruns in the sector.

Second, the Dutch infrastructure sector is challenged by an enormous accumulation of deterred infrastructure assets in combination with a large number of post-World War II assets that are nearing their technical end-of-life. This results in a huge task of renovation and replacement of infrastructure assets across all tiers of government in the next few decades (Bleijenberg, 2021). Currently, both the available budget and capacity are considered tight. Third, the overall infrastructure is, compared to other countries, considered of exceptionally high quality in terms of, e.g., connectivity, efficiency and reliability of roads, waterways and railways (World Economic Forum, 2019). This has consequences for the standards to which circular alternatives should comply.

Mission arenas

We found that, because the mission was both centrally governed and several platforms and networks exist in which the mission directions are developed, two interrelated mission arenas exist (Figure 2): (1) Transition Team Circular Building Economy (hereinafter referred to as 'Transition Team'); and (2) platform Circular Building '23 (hereinafter referred to as CB'23). Both mission arenas concern both the infrastructure sector and the building construction sector, which largely shape the built environment. Although both subsectors are addressed in the overall goals and strategies, for example, in the *Transition agenda circular construction economy*, their operationalization is discussed in separate strategies and policies.

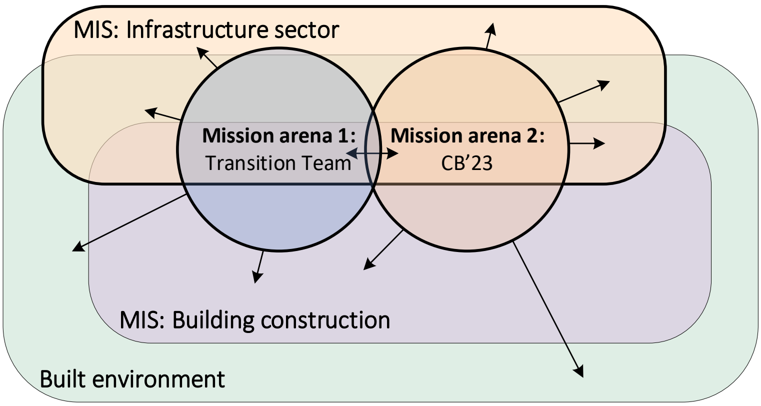


Figure 2. Schematic outlines of the MIS and two major mission arenas.

The Transition Team (Mission arena 1) forms a rather formalized arena. It was established in 2018 by the Dutch Ministry of Economic Affairs and Climate (EZK) and the Ministry of Infrastructure and Water Management (IenW) to shape and steer the implementation programme towards circular construction in line with the *Transition Agenda*. It consisted of 16 individuals who represented ministries, other government bodies, universities, market organizations, and financers, including their relations with other sectoral actors, both from building construction and infrastructure.

CB'23 (Mission arena 2) is a platform established in 2017 by Rijkswaterstaat, the Dutch Public Real Estate Agency and the Dutch Normalization Institute to establish a shared basis for circular construction aimed at both building construction and infrastructure. In contrast to the Transition Team, CB'23 is aimed at sector-wide participation and encourages all interested actors to join. The result is a heterogeneous platform of over one hundred participants from almost as many organizations contributing to several thematic working groups. The output consists of widely supported and publicly available guidelines to encourage circularity in construction. Active alignment exists between arena 1 and arena 2 with several individuals who participate in both the Transition Team and the board of CB’23. As a result, there is no single place where the direction of the transition towards circular infrastructure is governed. Instead, there is an interconnected and dynamic collection of actors who operate in varying arenas. Apart from these central mission arenas that aim to direct the transition at large, specific arenas exist that aim at specific parts of the transition, such as the agreements for specific material groups such as concrete [Betonakkoord] and steel [Bouwakkoord staal]. These are not separately studied but merely considered as context for the sectoral arenas.

2.5.3 Functional analysis

The performance of the MIS functions (Table 2) is summarized in Table 4. Based on these functions, the dynamics in the sector are explained in greater depth in the next sections.

Table 4. Summary of the results of the functional analysis per function.

Code	*Function*	*Performance*
F1	Entrepreneurial activities	Even though the CE theme is widely shared across the industry, the actual initiatives in practice are still quite low in number and impact. Moreover, the current focus is on pilots and experiments, rather than process and organizational changes.
F2	Knowledge development	Huge steps have been made in the development of circularity knowledge. However, some themes are still underdeveloped, such as distance-to-target knowledge, as well as knowledge on the tactical level.
F3	Knowledge diffusion	Despite a relatively high willingness to share circularity knowledge through showcase examples and network events, access to relevant knowledge is challenging, especially for newcomers. Also, cross-project knowledge diffusion and learning between projects and organizations remains problematic.

Code	*Function*	*Performance*
F4		
F4a	Problem directionality	There are several (policy) initiatives aimed at aligning the CE mission with societal problems, but the perception of circularity is rather contested and highly sector-specific. In addition, the relation with other missions, such as sustainability, is perceived divergently.
F4b	Solution directionality	Several solution directions are in a fair stage of development, but there is still a lack of consensus on the priorities between those solutions. This exploration is delegated to the market, rather than being top-down directed. Yet, public clients play a significant role in the solution directionality through their purchasing power.
F4c	Reflexivity	The knowledge infrastructure and distance-to-target knowledge are insufficient for reflexive governance on circularity. However, there are major current developments in these aspects. The circularity strategy is continuously adapting and evolving to new developments and insights on problems and solutions.
F5	Market creation and destabilisation	The main instrument to steer markets is the purchasing power of public clients. Also, a lot of effort is being put into experimenting with novel business models, circularity-included procurement, and increasing the minimum circularity requirements, but those still insufficiently apply to conventional projects.
F6	Resource (re)allocation	The allocation of funds for circular initiatives is increasing but insufficient. However, a larger challenge is the lack of capacity in terms of circularity-focused employees and experts to adapt (non-circular) processes and practices.
F7	Creation and withdrawal of legitimacy	Generally, the legitimacy of circularity is high throughout the sector, but its priority is still too low compared to, e.g., the energy transition or traditional infrastructure values such as traffic hindrance.

Entrepreneurial activities and experiments for circular solutions (F1)

The entrepreneurial activities and experiments for circular solutions are increasingly visible in practice. Circularity appears as a topic in almost all organizations and is covered in virtually all business strategies. This goes hand in hand with an increasing societal awareness concerning squander and waste. Yet, several interviewees stressed that most individuals and infrastructure projects did neither actively address circularity nor circular innovation. A foremost reason mentioned was that circularity is generally not an indicator to measure the performance of projects or individuals. Furthermore, the degree to which circularity is implemented differs markedly between organizations but is, generally, low. The reasons mentioned for the low proactivity towards circular solutions in market organizations were small profit margins, overcapacity in sub-sectors and tight and prescriptive procurement procedures.

Given the large dependency of infrastructure works on public clients, the lack of market initiative is largely a result of a circularity-unfriendly procurement practice. As indicated by a contractor, “often you aren’t even going to look for novel solutions, because [the clients] request a proven technology”. In addition, public clients seem to struggle with handling unsolicited proposals, which hampers circular market initiatives. Nevertheless, we found several networking and collaboration initiatives, comprising both market parties and clients, that explore the direction to innovate and implement circular actions. The result can be seen in the increasing number of pilot projects that address circularity.

Development and diffusion of circularity-enabling knowledge (F2, F3)

The knowledge required to transition is being generated very rapidly by many types of organizations, particularly the larger organizations, as well as by academia. According to several interviewees, knowledge of conditions and processes for circularity is being driven largely by commissions from ministries and wider networks. Despite the many platforms and networks, individual organizations often develop circular knowledge to increase their competitive advantage, rather than to deliver sectoral or societal benefits. Yet, market parties acknowledge increasingly the benefits of sharing knowledge – particularly given the overall work overload, which reduces the risk of losing competitive advantage. Regardless of the availability of knowledge, access to it for actors new to the topic is considered problematic, especially in terms of the complexity and specificity of circularity knowledge. This problem holds particularly for smaller organizations that cannot spend a lot of time searching for, developing and applying circularity knowledge.

The results indicated a major knowledge gap related to distance-to-target knowledge of material and waste flows, material properties and future resource demand. This is the knowledge that is required to make circular decisions from the perspective of governance and management, which creates challenges for both the provision of giving a proper perspective to the market and the long-term allocation of funds. The lack of perspective and long-term funding hampers wider market investments in circular operations. Another commonly mentioned gap was the lack of tactical knowledge to enable the implementation and operationality of the strategies, on, for example, supply chains and organizational processes. Nevertheless, developments are increasingly initiated by client organizations in particular to develop this type of knowledge.

Alongside the knowledge in practice, we found that scientific knowledge on the topic has experienced a large growth since 2015. As a researcher put it in one of the interviews, "I think that [development of circularity knowledge] is rapidly developing in a systematic way, albeit fragmentedly". Although this knowledge is often more fundamental and not necessarily aimed at the infrastructure sector, it gets diffused and adopted in the network through collaborations and network initiatives. Furthermore, circularity seems to become increasingly a topic in civil engineering and construction management education. This helps to diffuse scientific and professional knowledge to both junior employees and experienced professionals.

However, sharing and adopting lessons and knowledge within organizations and between projects appears to remain problematic. A clear coordination of this knowledge development and diffusion throughout the sector seems to be lacking, despite the conceptual alignment between the various initiatives and the mission arenas. Recently, various initiatives have been initiated to overcome this barrier, such as Communities of Practice (CoPs), implementation programmes and client meetings to align circular ideas and strategic agendas. As a consultant confirmed, "[there are] more and more places to showcase good circular examples". This helps to diffuse knowledge and inspire others. Yet, despite the large amount of available circularity knowledge and pilot projects, the diffusion of information, knowledge and lessons learnt was found to be one of the foremost bottlenecks impacting the transition to circular infrastructure.

Directionality of the problem and solution pathways (F4a, F4b)

The problem-solution analysis shows the background of the problem and solution pathways regarding circular construction. But how are these problems and solutions directed and how is this directionality perceived? We found that circularity in the infrastructure domain should be understood as *circular construction* aimed primarily at maximizing value per unit resource, reducing the use of virgin materials and reducing waste creation, whether or not to reduce the overall environmental impact. While several interviewees stressed the importance of treating circularity as a separate theme to safeguard governability, most of them argued that circularity must be viewed integrally with other societal problems. These include the goals stated in the formal policies, such as CO_2 emissions and energy use, but also issues like long-term cost reductions and cost efficiency. Despite these differences in interpretation, several interviewees referred to the CB'23 guidelines for a widely supported definition of circular construction which was also adopted by the Transition Team. The Dutch formal problem for infrastructure is nevertheless poorly aligned with the circularity goals formulated by the overarching circularity strategy report and the monitoring agency (Netherlands Environmental Assessment Agency; PBL).

Notwithstanding the wide debate on and the embrace of circularity, most interviewees stated that the priority of circularity remained too low compared to other themes, such as traffic hindrance, cost efficiency or accessibility to achieve the policy goals for 2030 and 2050. This holds not only true for top-down policy, but also how for instance project managers are assessed on their performance. In this current, early transition stage, the predominant implementation activities are aimed at pilots and experiments to explore circular solutions in infrastructure, rather than at becoming embedded into regular infrastructure projects and practices. Increased by the long lead times of infrastructure, this has resulted in meagre changes in terms of output results in the short term.

Given the lack and poor coordination of standardization of solutions, it remains unclear what the dominant solution pathways will be. These can range from bio-based materials to increasing reusability to reorganizing asset management. However, several interviewees mentioned that various kinds of infrastructure require different kinds of circular solutions. To illustrate the unclarity of dominant solutions, one civil servant pointed out that: "[…] it is not so much the circular solutions themselves that are under debate, but rather how and to which extent each solution should contribute to solving the problems".

Also, more and more preconditional issues have come to light that are required for the system to become more circular. These include restricting legislation, organizational processes, project approaches and procurement mechanisms. Although rules and legislation were mentioned as instruments to direct the solution space, a policymaker highlighted the balancing act of "trying to move the market in a desired direction, [while allowing] space for their organizational changes and innovations". This remark confirms the widely shared perception that it should not be the role of the government to choose specific solutions, but rather to provide the conditions for the market to come up with the best solutions. This finding is consistent with the dominant public governance paradigm in the Netherlands as discussed in the structural analysis.

Reflexive governance (F4c)

Concerning the governance of the mission, we found that the large public clients in particular developed several roadmaps, transition pathways and scenario studies to provide longer-term direction to the transition activities and accompanying solutions. These relate to several monitoring and assessment activities, both within the sector and across sectors. At the project, organizational, sectoral and cross-sectoral levels, individual circularity actions and policies are generally assessed and evaluated. Nevertheless, due to the lack of distance-to-target knowledge, it appears difficult to determine the contribution of certain policies or actions and to adapt the coordination and directionality strategies accordingly, especially on an organizational or project level. As one public manager admitted, "we don't know the actual environmental impacts of actions and what is needed to reach the [CE] targets, […] so that makes it very difficult to steer". A big challenge in governing the transition, regardless of the monitoring and evaluation effort, is the long-term planning in infrastructure that is strongly connected to the sector's structure. As long as circularity is not part of these long-term strategies, planning and portfolios, the governance of circularity principles beyond newly built assets remains impossible.

Interviewees also mentioned that it is difficult to learn across projects, even when such projects are specifically labelled circular. This is partly because there is no central knowledge infrastructure in place that facilitates governing, based on lessons learnt in practice. Next to developing knowledge, in general, to allow for reflexive governance, a major consequence appears to be the challenging persuasion of politics to systematically allocate funds and build capacity for circularity.

Creation of markets for circular solutions (F5)

Currently, circular market creation appears to be aimed primarily at experiments and pilots for circular alternatives. To create markets for circularity in a regular project setting, the public clients should take a leading role, since, on the one hand, the market is insufficiently organized to do so and, on the other hand, public clients have virtually all the means at hand to steer the transition. As a contractor mentioned, "we are a demand-driven organization and if we do not adhere to the demand, we won't win tenders". Procurement, especially, was mentioned as a major tool to steer circularity opportunities and to shift from procuring projects to longer-term collaboration forms that better incorporate the lifecycle principles of CE.

Nevertheless, there is a large variety of competencies of public clients to create the conditions for circular markets. Moreover, there is a lack of coordination between them to move the market in a circular direction. Next to creating markets with circularity-friendly procurement, several interviewees identified the provision of perspective for future circularity demand as a major bottleneck to the market initiative. In that respect, interviewees urge government clients to be prepared to allocate additional funds to create circular markets expecting that, when these markets are in place, costs will be lower than if the current linear way of working would be continued.

An ongoing debate in the domain of circular business models is to what extent these contribute to the overall circularity mission. One dilemma cited was the following. Extending producer or contractor responsibility, e.g., by service contracts, may, on the one hand, result in incentives for resource efficiency, while, on the other hand, it could reduce the control of the client to steer for circularity in the long run, particularly considering the evolving meaning of circularity.

Another challenge mentioned was that it depends on the subsector to what extent clients can exert control on circularity requirements. This is strongly linked to the market capacity, reliance of market parties on infrastructure works and the number of contractors. Nevertheless, according to interviewees, new markets should be created, and client organizations should steadily increase thresholds associated with, e.g., recycling rates, CO_2 thresholds or waste quantities. This can include award/punishment mechanisms for material use and waste creation. Still, as one consultant revealed: “The danger with regulations [for increasing thresholds] is that parties take that these as a minimum norm, rather than trying to go beyond it”. Hence, a disadvantage of such strategies is that these aim at pushing laggards rather than stimulating frontrunners and early adopters to go even further. This connects to the dilemma regarding the extent to which public clients are responsible for keeping all market parties on board, as opposed to leaving structural laggards behind.

Finally, our data indicates several ways of stimulating the market at large. Pricing mechanisms or revisions of the tax system from labour to resources were often mentioned. This is in line with structural market barriers beyond the sectoral boundaries (Kirchherr et al., 2018). Currently, the government has several subsidy schemes that cover circularity, such as the Small Business Innovation Research (SBIR) programme for circular bridges and grants for replacing fossil-fuelled equipment with electric alternatives. Yet, these do not seem to have led to many concrete advancements on a sectoral scale. One foremost opportunity to offer conditions for circular alternatives in regular projects would be to replace strict specifications with more functionally specified tenders, which is already happening on an accumulative scale.

Availability and allocation of resources (F6)

Funds in infrastructure are generally public. Hence, they are connected strongly to political decision-making. Most interviewees agreed that there are not enough funds available to finance the changes necessary for circularity – particularly in the long term. Lack of distance-to-target knowledge, including sector-wide material flows and recycling and reuse percentages, were mentioned as important barriers to acquiring long-term funds. Next to the mere availability of funds, we found that it is important to link (innovative) construction funds to the maintenance and replacement challenges in the infrastructure sector, especially for public clients. Consequently, it is not only the number of resources but also the type of activities to which those resources are linked that are needed to effectively stimulate the transition.

The data further suggested that politics should allocate more funds to accompany their increasing targets and ambitions regarding circularity – particularly for smaller local governments. As one public manager put it: "When you get an assignment without the requisite means, you should think carefully about the extent to which you are going to execute the assignment". As such, interviewees argue that decision-makers, managers and politicians are insufficiently able to realize that circularity could lead to cost reductions in the long run, especially when, e.g., CO_2 taxes in the future push up the price of virgin materials. However, as another public manager argued: "Despite attention for [CE] might be too low, advocates of safety or other themes probably would probably argue for the same, […] given the overall shortage of resources for infrastructure and particularly its maintenance and operation".

Funding of circularity is often coupled with sustainability in general. As a result, circularity initiatives can often be financed with climate change-related funds, e.g., carbon reduction or where the word *climate* is attached. When used for circularity, available resources are often allocated to specific pilot projects and technologies, while for making steps in circularity, resources need to be allocated to structural organizational and operational change. Such investments are still marginal, specifically within market parties. Although it was noted that larger contractors tend to invest increasingly in circularity, the extent is still considered too low and too slow.

Despite the abovementioned lack of financial resources for innovation, the lack of capacity (i.e., employees dedicated to and knowledgeable on the topic) seems to be a pressing challenge, too, which is reinforced by the overall labour shortage in the Dutch construction sector. Nevertheless, in line with Gerding et al. (2021), an increasing number of employees in public and market organizations are showing an interest in circularity or are even dedicated to it. Also, circularity is increasingly being integrated into educational programmes, which helps to equip future employees with circular knowledge and practices. At the same time, an increasing number of young graduates want to work only in companies with a clear and progressive vision of environmental issues.

Legitimacy for circular infrastructure (F7)

Overall, there seems to be considerable legitimacy for the circularity theme throughout the Dutch infrastructure sector. This can be explained partly by the clear link to national and supra-national agreements and, also, because of the concept's relation with long-term economic and environmental benefits. Nevertheless, there are other competing themes with higher priority in the Dutch infrastructure sector, such as the energy transition and nitrogen problems that prevent construction projects from starting due to the refusal and delay of building permits due to environmental reasons. Their influence can, however big the circularity legitimacy, result in limited action. An often-mentioned explanation is that other themes are easier to quantify, measure and compare, particularly in the procurement stage. There is also increasing societal support and a sense of urgency for the circularity theme. This has two benefits. First, individuals project their concerns in their daily work and, second, individuals, such as shareholders and civilians, increasingly call for circularity.

Notwithstanding legitimacy on an abstract level, the legitimacy of specific solutions is not as univocal. Interviewees mentioned the considerable debate on the solution directions and the roles that specific pathways can play, for example, bio-based materials and design-for-reuse. Some seemed concerned about the suitability of regulation for circular practices. Others argued that existing legislation offers plenty of space for circular practices and solutions when making use of the 'grey area', despite restricting boundaries – particularly regarding ownership.

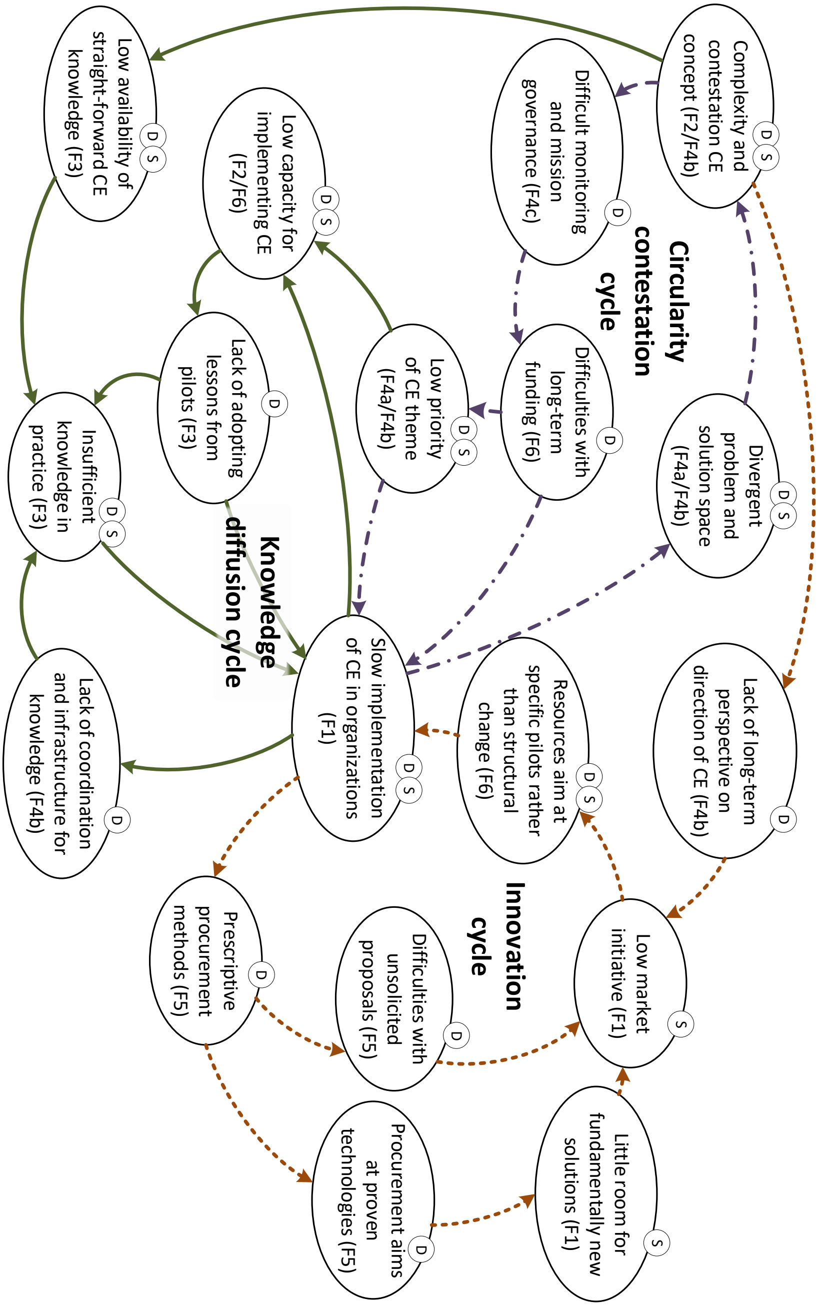
Most interviewees did not experience any organized anti-circularity lobby, probably because most subsectors see a potential business case in circularity. Nevertheless, a strong lobby can be expected, particularly from the bulk material subsectors. As one consultant stated, "Everyone in the fossil sectors understands by now that this won't continue forever. […] But despite [recent developments], we don't have the sustainable alternatives yet – which they currently exploit". Contrarily, sectors that see an opportunity in circularity principles, such as the wood sector, are actively coupling lobbying activities to the CE mission.

2.6 Analysis of the barriers towards a circular infrastructure industry

By linking the insufficiencies in the functions to specific structural or activity-based causes as discussed in the previous section, three cycles that amount to systemic barriers facing the Dutch infrastructure sector have been identified and visualized in Figure 3. These three major cycles were labelled as: (1) the *circularity contestation cycle*, in which the meaning of circularity is at the centre; (2) *the knowledge diffusion cycle*, in which the diffusion and adoption of circularity-supporting knowledge have a central place; and (3) the innovation cycle, in which innovation, market creation and market initiative are

The first, *circularity contestation cycle*, centres on the observation that both the problem and the solution spaces of circularity in infrastructure are contested. That is, there is a divergent understanding of the problem–solution interaction of circularity within the Dutch infrastructure sector. This increases the complexity of searching for and developing circular solutions because, particularly in the client–contractor relationships, there is a lack of alignment between different understandings of which solutions are the most circular. This contestation of circularity, reinforced by the long lead times and lifespans of infrastructure, leads to difficulties in reflexive monitoring as it is unclear how the benefits of certain activities or solutions can be allocated to the overall circularity progress. A lack of clarity as to progress adds to the complexity of governing the CE mission. Given the politicized environment in which infrastructure is positioned within the public sector, a lack of clear contributions from circular solutions to the long-term goals also hampers the long-term funding of the CE mission, particularly for measures where the circularity benefits are not directly visible (e.g. on asset prevention or lifespan extension). This results in the slow implementation of circularity within organizational processes which, in turn, contributes to a fragmentation of circular initiatives and hence a divergent understanding of circularity.
central. The three cycles are explained in detail below.

The contestation of the circularity concept and the resulting low priority given to it also has consequences for the *knowledge diffusion cycle*. Since there is only very limited straightforward and explicit circularity knowledge available to the parties, who also have only a limited capacity to execute projects, it is challenging to apply knowledge in practice. This makes it difficult to implement circular knowledge in organizations. First, slow implementation of knowledge in organizations leads to a failure to allocate capacity to act in accordance with CE principles. This is reinforced by the low priority given to the circularity compared to other themes, such as risk mitigation and traffic continuity, which largely stems from the lack of structural funding. As a result, circular solutions often



*Activities related to the demand side (e.g. clients) are indicated with a "D" and to the supply side (e.g. contractors) with an "S".

Figure 3. Three causal, hampering cycles towards a circular infrastructure sector.

remain in the pilot project stage, with only a little attention given to wider applications within more conventional project settings. Second, the very limited implementation of circular knowledge results in a lack of knowledge infrastructure for circular practices. This leads to the poor availability of knowledge for non-experts which, in turn, results in a slow implementation in organizations.

The third, *innovation cycle* predominantly results in a lack of novel circular alternatives. Conventional tenders can be characterized by their use of rather prescriptive procurement methods. This can partly be explained by the strict procurement laws and has the effect that it discourages the introduction of unsolicited and novel proposals by market parties. Further, and sustained by the sector's risk-averse culture, tenders are often aimed at acquiring proven solutions, which leaves little room for novel circular alternatives. This is a particularly important issue for material innovations, which are considered key in the wider transition towards a circular infrastructure sector. Together with the lack of a long-term direction for circularity in terms of solutions and goals, due to the contestation of circularity, as well as the tight profit margins in the sector, this results in limited initiation and uptake of circular market-led innovations. As a result, clients focus on stimulating market solutions through pilot projects, with little emphasis on implementing more fundamental organizational changes. In turn, this maintains the prescriptive nature of the process of infrastructure procurement by client organizations.

In sum, three main sets of interrelated cyclic barriers that impede the transition towards a circular infrastructure sector in the Netherlands have been identified. An issue that affects all three cycles is the contestation of the meaning and operationalization of circularity. Overcoming the self-reinforcing nature of these cycles requires interventions on the systemic level.

2.7 Discussion

2.7.1 CE dynamics and barriers in the Dutch infrastructure sector

We have identified three major cycles that hamper the transition to circular construction industry in the Netherlands: (1) the *circularity contestation cycle*, reflecting the contestation of the CE mission; (2) the *knowledge diffusion cycle*, covering the difficulties in knowledge diffusion and adoption in projects and organizations; and (3) the *innovation cycle*, which addresses difficulties in creating a market for circular innovation. These findings suggest that a greater focus on organizational and institutional aspects is needed to facilitate the multidimensional conditions required for the development, diffusion and adoption of circular solutions. This contrasts with the rather technological focus in current research into achieving circularity in construction and infrastructure (e.g. Munaro et al., 2020 and Charef and Lu, 2021). Moreover, the systemic nature of the findings points towards deeper causes of unsustainability than the stand-alone solutions or replacements that have been studied about the circular practices within public-sector organizations (e.g. Klein et al., 2022), especially when pursuing solutions that fundamentally prevent and reduce the use of resources in infrastructure.

Nevertheless, the current focus on experimenting and exploring the subject is consistent with what one might expect – and even encourage – at this current, early stage of the transition (Rotmans & Loorbach, 2009). This is likely to also be the case in other European infrastructure industries, given that they all are regarded to be in an early stage of transitioning to a CE (Giorgi et al., 2022).

Furthermore, several of our findings stand out when considering CE as a mission. The transition towards a circular infrastructure sector is governed in multiple spaces, each with its own specific goals despite being concerned with the same overarching mission, while the formal circularity strategy is scattered among several ministries. This increases the complexity and requires other coordination mechanisms to converge the problems and solutions beyond actors being either in or out of a single arena. This point is strengthened by the findings of Çimen (2021), who identified an overall failure to develop circularity research that acknowledges the stakeholder complexities in circular practices in the construction industry.

Moreover, we identified a remarkably small number of activities or developments that were aimed at actually removing non-circular system structures or practices, something which is again reflected in other research (e.g., Benachio et al., 2020; Mhatre et al., 2021). As a consequence, circular solutions seem to have to fit within or be added to the current non-circular system, rather than aiming to replace or fundamentally restructure the current structure or dynamics of the infrastructure sector. However, for a system transformation to take place, circularity must be embedded in the system itself which, by definition, calls for the withdrawal of non-circular practices. This calls for substantially other governance approaches (Stegmaier et al., 2014). The large number of recycling and circular design initiatives compared to the limited number of, and difficulties associated with more impactful systemic resource reduction strategies illustrate this finding (Joensuu et al., 2020). The highly institutionalized regime actors that benefit from maintaining the status quo contribute to this (Leiringer et al., 2022). Hence, the overall phasing out of hindering practices, which is essential for achieving the mission goals, is largely lacking.

2.7.2 Managerial and policy implications

Here, we note a few implications of our work that may be relevant to other European infrastructure sectors and beyond. First, our results indicate a highly contested understanding of circularity throughout the sector. Highly strategic policy changes at the ministerial level could address the difficulties around the contestation of the circularity concept. This connects to a lack of directionality by governments, both as policymakers and as clients, who do little to incentivize market parties to invest and innovate for circularity. Further, central public organizations, such as ministries and their executive agencies, are in a position to organize and coordinate the diffusion and management of knowledge that is necessary to implement circular measures. Since the mission, as a core object, comes with different change and innovation dynamics such as the plurality of potential technological solutions and inherent normative notions, both reflexive governance and coordinated participatory action become ever more important (Ferraro et al., 2015).

Moreover, procurement is considered a powerful instrument for clients to further circularity developments, not only because clients can act as leading customers, but also because they can, particularly in a pre-contractual stage, direct and organize demand in line with mission-driven procurement strategies (Schotanus, 2022). However, procurement power should not be overestimated concerning the circularity transition; the more ambitious circular strategies (e.g., lifespan extension and reduced demand for new assets) can only be realized in a pre-procurement stage, such as in long-term planning and budget allocation, and post-construction phases as applied in asset management and asset removal activities. The focus should therefore be, beyond building more-circular novel assets, on asset management.

In this regard, public client organizations are crucial in organizing processes for circularity in the infrastructure sector, particularly regarding the more fundamental circular solutions, such as reducing the demand for resources and extending lifespans. Vicious cycles can be breached by translating mission-driven circularity strategies into organizational processes that have circular choices as default outcomes. This approach can be initiated from the domains of asset management and knowledge management, yet it should also be integrated into data management and portfolio management.

2.8 Conclusions

Our MIS-based analysis of the transition towards a circular Dutch infrastructure sector has revealed several causal chains of dynamics related to activities, practices and structures of the sector. In line with findings from previous transition research (e.g. Wesseling and Van der Vooren, 2017), many of these causalities appear to be the result of lock-in mechanisms that are difficult to breach. These consist of self-reinforcing cycles related to the configuration of the socio-technical system, which only come to the surface when taking a systemic perspective on the transition. Since these causalities are multidimensional and embedded in the wider system, solving single issues or introducing single innovations or fixes will not suffice.

Studies on the socio-technical system level offer insights into barriers that are conditional on other barriers (Suurs, 2009). These insights can contribute to structuring and prioritizing domains of interest for construction management research. In our case, for example, the multiple systemic barriers seemed to relate, at least partly, to the equivocal interpretations of circularity. This has had a large effect on the overall transition towards a circular infrastructure sector in the Netherlands and hence highlights a critical point on which to focus research, policy and management efforts. Only systemic analyses can identify such deep-seated barriers to change.

The findings from our case study enable us to reflect broadly on several levels of the functioning of the infrastructure sector when facing the need to undergo a circularity transition, and how one might develop approaches to disrupt the vicious cycles. Given the system interdependencies, one should consider the functioning of the system on the level of the cycles in addressing such barriers. In this respect, construction management research could make significant contributions by considering institutional and organizational aspects in context-specific construction and infrastructure settings.

2.8.1 Future research

This study has several limitations that create opportunities for future research. First, the study focused on a Dutch case, and it is recognized that transitions are highly context-dependent. For example, there are several characteristics of the Dutch infrastructure sector, such as the ‘polder model’ in decision-making, that might result in specific transition dynamics that have wider or more limited applications that future studies could identify. Furthermore, the analyses of the structure, dynamics, and barriers have been based on policy documents and interviews with practitioners from this particular context who provided their personal arguments based on individual perceptions of cause and effect. A study based on other data sources on circularity-related events, projects and initiatives might reveal deeper insights into the solutions and solution spaces that exist in practice to step beyond the perception of individuals. Apart from new potential findings, this would increase the validity of the findings and the generalizability of the recommendations made.

Second, the *system* we studied is inherently complex. By identifying key causalities, we aimed to simplify this complexity to several key factors and relationships in three major cycles. These simplifications lead naturally to limitations concerning revealing and explaining causality. Additional research could apply practice research, institutional theory or organizational sciences to find and explain mechanisms behind the causalities in detail and could reveal deeper mechanisms that explain these complexities. This might also lead to more detailed insights into the potential ways of strengthening positive causalities and breaching negative ones, by, e.g., policy interventions. However, rigid government interventions do run the risk of having only a minor or even an adverse effect on the transition in the traditionally highly institutionalized construction context (Leiringer et al., 2022).

Finally, the application of the analytical framework used (MIS) has its challenges, because it offers a snapshot of the system barriers at a moment in time, while the transition is an ongoing process. This makes it difficult to determine whether the barriers are present at only a specific point in time and to establish the extent to which they are persistent. Although well-grounded in the empirically well-established TIS functions, the novel MIS functions are not yet thoroughly validated in empirical cases. Doing similar research using other research frameworks, such as the multi-level perspective (MLP; Geels, 2004), is needed to increase the validity of the findings, possibly revealing new insights on systemic barriers and causalities of mission-driven changes and innovations.

2.8.2 Recommendations for policy and practice

Given the conclusions that highlight three vicious cycles, our work also leads to recommendations for policy and practice. Norms and regulations, both technical and processual, were in our results generally perceived as barriers to change, even when regulations are not legally confining the space for circular practices. Governments could address this by not only ensuring that norms and legislation enable circularity, but rather by ensuring that circular decisions are an integral part of these practices.

Convergence on the societal challenges that the circular solutions aim to address could be stimulated by making the problems and solutions more explicit, both in policy documents as well as in the stated goals and ambitions by clients. This would increase the directionality of governance. Another way to address the lack of univocality and directionality is to strengthen the coordination between circularity networking activities to avoid multiple circularity operationalizations. Here, ministries and other central government bodies should take a leading role, because of their ability to regulate and allocate resources and their commitment to the CE mission. A shift from the current focus on circular design towards more integral circularity solutions is required, decreasing the demand for resources and increasing the lifespans of existing assets. Nevertheless, in situations where both the problem and the solution spaces are divergent, which is the case in Dutch circular infrastructure, it is important to explicitly guide the convergence reflexively from a policy perspective and, above all, take on a learning-by-doing mentality rather than following prescribed policy pathways (Wanzenböck et al., 2020).

Furthermore, there is a lack of resources and infrastructure to develop, diffuse, adopt and implement knowledge. Organizational processes aimed at infrastructure for knowledge management regarding circular developments should be established, particularly in and between client organizations. This would not only require putting the knowledge exchange processes in place but also ensuring the capacity to apply knowledge in conventional project settings, particularly knowledge from pilot projects and exemplary ambitious projects that are characteristic of the sector. Another underlying cause for the problematic adoption of knowledge is the lack of incentives, particularly for market parties, to share circularity knowledge. Cross-project collaboration, such as programmes and strategic partnerships, which can be launched by public clients, would provide incentives to invest in circular solutions and reduce the competitive advantage of withholding circularity knowledge (Håkansson & Ingemansson, 2013). In turn, this would increase the propensity for cross-project applications of circular solutions.

The solutions proposed above, particularly the alignment of understandings of a circular future within the sector and developing a long-term perspective, would enable significant market investments. Currently, markets are not incentivized towards circularity although assessment methods to include circularity in procurement are rapidly improving. Circular innovations are often so radically different that they do not meet the current assessment and procurement criteria. This requires public clients to be more open to solutions that have a low technological readiness level (TRL; Lenderink et al., 2022). Here, first, clients should provide space in the procurement criteria for more radical innovations and, second, risk should be distributed more fairly between market parties and clients, especially since the benefits of the circular solutions often only become apparent over the long term. Hopefully, this will lead to a situation in which market parties prioritize adopting circular solutions without specific calls from the client since only doing the bare minimum would lead them to become side-lined in future projects.

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chapter 3

operationalizing contested problem-solution spaces: the case of dutch circular construction

Abstract: In shaping collective responses to societal challenges, we currently lack an understanding of how to grasp and navigate conflicting ideas on societal problems and potential solutions. The problem-solution space is an increasingly popular framework for conceptualizing the extent to which problem-oriented and solution-oriented views are divergent. However, this reflexive framework needs operationalization to become useful in practice. We contribute to this debate by demonstrating how Q-methodology can be used to systematically identify, describe, and compare collectively held visions in relation to problems and solutions. We use the case of Dutch circular construction and identify three conflicting imaginaries that inform us about disagreement and common ground. We conclude by discussing how policymakers can use different approaches to navigate contestation, presumably mobilizing actors for a collective response.

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3.1 Introduction

Decision-makers are increasingly struggling with challenges that affect society and the environment (Schot & Steinmueller, 2018b). These challenges frequently fall into the category of *wicked problems* because they are characterized by inherent complexity and uncertainty, which contribute to their contested nature (Head, 2008; Rittel & Webber, 1973). More specifically, contestation arises as actors embody fundamentally conflicting ideas about the nature of the problems and their required solutions (Head, 2019; Kuhlmann & Rip, 2018). Wanzenböck et al. (2020) introduced the *problem-solution space* as a theoretical framework to conceptualize the extent to which views on these problems and solutions are divergent (i.e., contested). In this increasingly popular framework, views on problems and solutions exist, unfold, and interact and may diverge or converge over time.

Divergent ideas about problems and solutions cause actors to have radically different imaginaries of (un)desirable futures. Imaginaries are intersubjective insofar that actors may (implicitly) share visions once constructed around similar values and worldviews (Jasanoff & Kim, 2015). Contestation thus emerges when different groups hold contradicting imaginaries (Hess, 2015; Kim, 2015). Contestation represents a significant challenge for decision-makers because neglecting or misunderstanding disagreement can further problematize wickedness by prompting standstills, exacerbating conflict, or creating new problems. Decision-makers do not "always 'know best' or 'act best' in understanding problems and proposed solutions" (Kirchherr et al., 2023, p.4). They are therefore in need of novel approaches for collective sensemaking to mitigate the risk of reflexivity failures (Garud & Gehman, 2012; Weber & Rohracher, 2012).

Although the problem-solution space offers an important conceptualization of the (divergence of) imaginaries surrounding problems and solutions, there is an explicit demand for the framework's operationalization (Wanzenböck et al., 2020). In the absence of this operationalization, decision-makers inadequately understand what divergent imaginaries exist, how these relate to each other, and how these are distributed among actors. Without operationalization, decision-makers are insufficiently informed about the extent to which challenges are contested and how this contestation can be navigated. As a result, they could overlook or exclude viable problem understandings and solution pathways (Wesseling & Meijerhof, 2023).

This chapter contributes to the reflexive governance of transitions (Voß & Bornemann, 2011) by demonstrating how the contestation dimension of the problem-solution space can be operationalized. It does so by illustrating how divergent imaginaries about problems and solutions can be identified, described, and compared using Q-methodology to better understand the way and extent to which challenges are contested. Q-methodology is a widely adopted research method that helps understand the heterogeneity of intersubjective perspectives (Brown, 1982; Stephenson, 1935). By revealing opposing imaginaries, this chapter demonstrates how decision-makers (e.g., policymakers) can reflexively learn about alternative understandings of the problem-solution space of a given societal challenge (Feindt & Weiland, 2018). Continuously reflecting on the directionality of transformations allows for more tentative forms of governance that are more responsive to stakeholder worldviews despite interpretive flexibility (Bijker, 1987; Kuhlmann et al., 2019; Stilgoe et al., 2013).

To demonstrate this approach, we use the case of the Dutch circular construction in which the government has set out a contested imaginary, which we call *'Circular construction by 2050',* and which is being implemented through policies (Chapter 2). This chapter therefore also provides case-specific insights that could help policymakers align imaginaries for more collective responses.

In what follows, this chapter first elaborates on its theoretical background (Section 3.2), followed by an explanation of the chapter's methodology (Section 3.3). This section also introduces and justifies the case that is chosen for the chapter. Section 3.4 proceeds by describing the identified imaginaries after which Section 3.5 compares these to understand the contestation. The chapter concludes by discussing different ways contestation could be navigated, and by reflecting on the chapter's contribution (Section 3.6).

3.2 Wicked problem-solution spaces and contested imaginaries

3.2.1 Problem-solution spaces

Due to the enduring nature of wicked problems, solutions to these problems are deemed provisional, while the problems themselves are never solved. Provisional solutions strive to unfold "a never-ending discourse with reality, to discover yet more facets, more dimensions of action, more opportunities for improvement" (Dery, 1984, pp. 6-7). Wicked problems do therefore not have a 'stopping rule' (Rittel & Webber, 1973). Rather than 'solving' these problems, scholars speak of 'resolving', 'coping with', and 'managing' wickedness (Head & Xiang, 2016; Xiang, 2013).

The problem-solution space underlines this tentative and wicked nature of problems and solutions. Wanzenböck et al. (2020) provided various illustrative case studies to show that views on problems and solutions may diverge or converge (Figure 4). There are, for example, increasingly more convergent views on the problem of obesity while there is widespread disagreement on which of the numerous interventions are needed to tackle this. The self-driving cars example contrarily suggests that disagreement may also emerge on what problems some concrete innovations can resolve. While problems and solutions are open to dissimilar levels of contestation, developments around smoking bans, wind energy, and CCTV demonstrate how both problem-oriented and solution-oriented views can converge over time.

Next to the convergence of problem and solution framings, framings may interact in the sense that the framing of one suggests the framing of the other (Bacchi, 2009; Ison et al., 2014; Peters, 2005). For instance, the reduction of CO_2 emissions as a solution for climate change hints that CO_2 emissions are part of the problem.

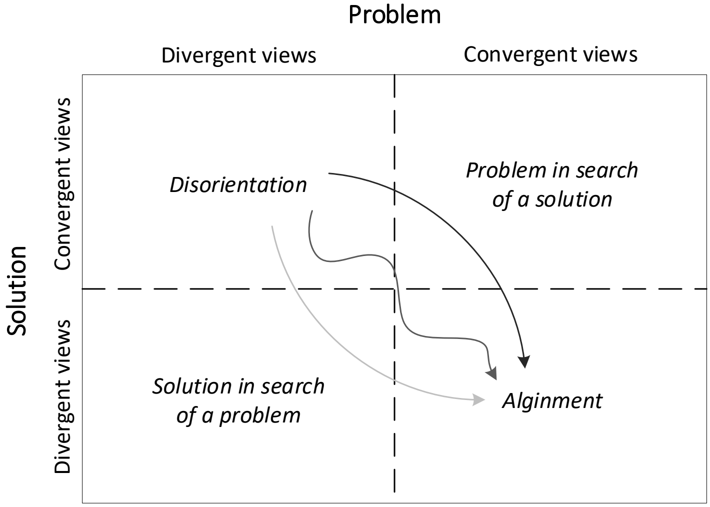

Figure 4. The problem-solution space. Source: Wanzenböck et al. (2020).

More fundamentally, problems are contested because they can be framed as symptoms of higher-level problems and can be explained in numerous ways (Rittel & Webber, 1973). Solutions are contested as stakeholders embody radically different, or even conflicting, values and worldviews – solutions that meet one's preferences may displease those of others (Dentoni & Bitzer, 2015; Pesch & Vermaas, 2020). The number of possible solutions is also non-exhaustive, and these solutions are often impossible to test because they would change existing problems or create new ones (Rittel & Webber, 1973). As such, contestation often relates to the epistemic nature of problems, and the risks, uncertainties, and opportunities associated with potential solutions (e.g., Dignum et al., 2016; Ligtvoet et al., 2016). Sources of contestation are moreover exacerbated by the complexity and uncertainty associated with wickedness (Head, 2019).

Contestation is in many cases a future-oriented phenomenon because possible solutions are usually not yet developed and implemented. While contestation about future scenarios can relate to predictions (i.e., what *will* happen) and explorations (i.e., what *could* happen), it nearly always involves normative ideas (i.e., what *should* happen; Börjesona et al., 2006; Ligtvoet et al., 2016). These visions may be made explicit through the act of framing. Visions for (un)desirable futures tend to be collectively held even though only a selective group of actors actively partakes in the political discourse that emerges from explicit framings (Konrad & Böhle, 2019). Framings thus explicate only a fraction of collectively held visions in society even though nearly all visions have a performative function. As a result, disagreement is often obscured, undisclosed, and latent. An analytical shift from framings to collectively-held visions is therefore helpful in revealing and understanding contestation.

3.2.2 Imaginaries

Jasanoff and Kim (2015) refer to these collectively-held visions as s*ocio-technical imaginaries*, which they defined as: "collectively held, institutionally stabilized, and publicly performed vision[s] of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology."(p.5). As such, imaginaries represent normative socio-technical visions that are held by a group of individuals and which are publicly performed (Sovacool et al., 2019). Attaining these desirable futures through science and technology suggests that imaginaries contain a strong solution-oriented view that is constructed on present-day problems. Jasanoff and Kim (2015) argued that imaginaries can be utopian or dystopian, hinting that imaginaries do not necessarily emphasise problems and solutions equally.

Imaginaries are co-constructed and enable individuals to be connected by shared narratives, norms, and discourses, without having ever met. They are thus social constructs (Bijker, 1987) that implicitly or explicitly reflect matters of concern (Latour, 2004). They lay at the nexus of how society co-produces epistemic and normative understandings of the world, i.e., how things are and how things should be (Jasanoff, 2004). Imaginaries thus have a performative function as they shape the future by steering practices in the present (Delina, 2018). Imaginaries are inherently political (Granjou et al., 2017; Konrad & Böhle, 2019; Marquardt & Delina, 2019) because they inscribe a "vision of (or prediction about) the world" (Akrich, 1992, p.208) that imposes particular values and worldviews (Winner, 1980). Inspired by Haraway (1988, 1991), it may therefore be fitting to speak of 'situated' imaginaries as they reflect the values and worldviews of the 'imaginator'.

Indeed, governmental imaginaries that are publicly performed through policies (e.g. missions and strategies) “are associated with exercises of state power” (Jasanoff & Kim, 2009, p.123) and tend to spark contestation (Hermann et al., 2022; Sismondo, 2020). Yet, imaginaries are not merely held by authorities such as experts and governments, but are also created, held, and reconfigured by other types of actors (Smith & Tidwell, 2016). As a result, problem-solution spaces are associated with a constellation of different imaginaries that are held by a broad range of groups. These imaginaries exist in parallel, co-evolve, and constitute what Burnham et al. (2017) call the ‘politics of imaginaries’. In this political landscape, divergent views on problems and solutions are reflected by the existence of multiple imaginaries that generally clash (Hess, 2015; Levidow & Raman, 2020; Marquardt & Delina, 2019).

In this chapter, we operationalize problem-solution spaces as the plurality of contradicting, often undisclosed, imaginaries that shape conflict and practices in the present. Revealing what futures should (or should not) look like according to different stakeholders is a crucial reflexive exercise needed to learn from disagreement (Cuppen, 2012; Ligtvoet et al., 2016). Reflexivity can therefore play an important role in the alignment of imaginaries (Figure 4). For instance, governments could subsequently reformulate policies in such a way they resonate with the perceived problems and desirable solutions of other imaginaries (Huang & Westman, 2021). In what follows, this chapter discusses the case and method used to identify and describe conflicting imaginaries in problem-solution spaces.

3.3 Methodology

This study aims to identify, describe, and compare divergent imaginaries as an operationalization of contestation in the problem-solution space. In what follows, we first introduce and justify our selected case study, and then explain how and why Q-methodology can be used to identify the imaginaries of its problem-solution space.

3.3.1 The Dutch case: ‘Circular construction by 2050’

We selected the empirical context of the government-led mission *‘Circular construction by 2050’*. This case was selected for a variety of reasons. First, this circularity mission is broadly recognized to be highly contested in terms of both its problem and solution-space (Coenen et al., 2022b). The wickedness associated with circular economy (CE) is reflected by heated debates among actors. For instance, practitioners question whether CE could even address environmental concerns and some believe it may have become a goal in itself (Calisto Friant et al., 2020; Corvellec et al., 2022). These divergent views on problems and solutions indicate that *'Circular construction by 2050'* does not fall into the 'alignment' quadrant of the problem-solution space (Figure 4). Moreover, its institutionally fragmented character and the sector's dependency on public funds are believed to invite hostility between public and private parties.

Second, the construction sector is relevant because its large use of natural resources and waste creation suggest that a transition to circularity can have a major impact on society and the environment (Ghaffar et al., 2020). Third, although the Dutch circular construction sector is a frontrunner in the domains of waste management and reuse innovations, it is still in an early transition phase (Giorgi et al., 2022). Fourth, the Dutch government was one of the first to issue a top-down policy on circular construction. The contested problem-solution space, institutional fragmentation, high stakes, and early transition stage in combination with this top-down approach indicate that various imaginaries presumably coexist with the imaginary *'Circular construction by 2050'* that is articulated through the government-led mission. This provides for a rich empirical setting to operationalize the problem-solution space. The government-led mission and its context are as follows.

In 2016, the Dutch government set out a mission for the Netherlands to be fully circular by 2050 (IenW & EZK, 2016). This mission was divided by the ministry into five priority sectors, including construction. The construction mission includes both building construction and the infrastructure sector, and as such addresses the entire built environment. The imaginary *'Circular construction by 2050'* was accompanied by a CE strategy report that introduced three objectives: (1) the high-grade utilization of available resources and waste flows; (2) the substitution of fossil and non-sustainably produced resources by widely available and renewable alternatives; (3) and the rethinking of consumption in conjunction with the reconfiguration of products and production methods. The same strategy report acknowledges that CE should be understood as a utopian vision to mobilize actors in a shared direction. It is idealistic in the sense that attaining such a fully 'closed' system is unlikely because of inevitable waste flows.

A transition team was installed for the construction sector that contained both policymakers and representatives of various stakeholder groups, including construction firms, engineering firms, national and regional clients, knowledge organizations, and interest groups. This team issued a strategic agenda that lays out how they believe the construction sector should be transformed into a circular one by 2050 (Transitieteam bouw, 2018). It directs efforts from a policy perspective towards developing a circular market, measuring circularity, establishing and implementing policies and legislation, and enhancing knowledge production and diffusion. In addition, it functions as the main advisory group to the Ministry that is responsible for circular construction.

In 2019, the Transition Team set out annual Implementation Programs which monitored the mission's progress, prioritization, and policy landscape (BZK, 2019). The focus shifted in these strategies increasingly from addressing resource efficiency to a more integral view on environmental sustainability and economic viability, including CO_2 reduction, energy efficiency, and reducing supply risks.

However, many circularity-related efforts in the sector did not align with the strategy presented by the Transition Team. Instead, efforts were often initiated by single actors who act in accordance with their own vision for circular construction (Chapter 2). Several of these efforts are now nevertheless considered prominent examples of circularity in the sector. The emergence of these alternative problem framings and the success of alternative solutions (e.g., bio-based materials and the reuse of building components) highlight the contested nature of the Dutch circular construction sector and reinforce the need for a more reflexive governance. However, this observation does not necessarily inform us about what problem-solution imaginaries exist and how they relate to each other.

3.3.2 Identifying imaginaries using Q-methodology

Q-methodology is an approach that helps understand an individual's subjectivity in relation to inter-subjectivity (Brown, 1982; Stephenson, 1935). The method has roots that stretch back to the early twentieth century and has been used in numerous fields to identify, describe, and compare views on topics of interest (e.g., Davies & Hodge, 2007; Gruszka, 2017; Rajé, 2007; Wolsink & Breukers, 2010). Scholars recently underlined Q-methodology's potential, but limited uptake, in the context of transitions (Hansmeier et al., 2021). Some transition studies have already used the method to study inter-subjectivity (e.g., perspectives, imagined publics) related to solutions like carbon taxes (Mehleb et al., 2021), electric vehicles (Lee & Park, 2023), resource management (Gruber, 2011; Kügerl et al., 2023; Streit et al., 2023), and biomass/gas (Bauer, 2018; Cuppen et al., 2010; Rodhouse et al., 2021; Silaen et al., 2020).

This chapter applies Q-methodology to identify, describe, and compare divergent imaginaries specifically in relation to the problem-solution space. Q-methodology is suitable for this purpose for at least four reasons. First, imaginaries are understood as "collectively held … vision[s] of desirable futures" (Jasanoff & Kim, 2015). Q-methodology is specifically designed to derive *collectively held* views from individual ones, and therefore goes beyond alternative research methods like interviews and focus groups. Second, it yields insights into the heterogeneity of these collectively held viewpoints (i.e., the degree of divergence) in contrast to finding the most generalizable viewpoint as commonly done in descriptive statistics. Identifying this heterogeneity is crucial not only for understanding and navigating conflict but also for the inclusion of minorities' perspectives. Third, it allows the researcher to identify these collectively held views within a debate without predefining groups. The respondents largely determine what shared views emerge from the analysis, reducing researchers' bias (Robbins & Krueger, 2000). Fourth, the collectively held views that emerge from Q-methodology allow for their systematic comparison by using their, so-called, factor arrays – the typical answers for each collectively held view. This systematic comparison contributes to the reproducibility of the approach.

Q-methodology involves six steps that include data collection and data analysis (cf. Cuppen et al., 2010). The first step concerns taking stock of the 'concourse'. This refers to the wide range of ideas that constitute the topic of interest. In order to identify the variety of views on the problems and solutions vis-a-vis circular construction, this chapter adopts data from Coenen et al. (2022b). The data concerns transcripts of approximately 90 minutes of semi-structured interviews with 20 stakeholders that relate to the imaginary *'Circular construction by 2050'*. These stakeholders were selected through purposive sampling to cover the heterogeneous institutional roles found in innovation systems as described by Kuhlmann and Arnold (2001), such as industrial actors (e.g., contractors, engineering firms), intermediaries (e.g., network organizations, standardization institutes, consultancies), consumers (e.g., construction clients), societal stakeholders (e.g., civil society organizations, representatives), governmental organizations (e.g., ministries), and research institutes (e.g., research institutes and universities). The transcripts are highly relevant as the interviews aimed to identify stakeholders' perspectives on the Dutch circular construction's problem-solution space. Interviewees were specifically asked what they believed were the problems that circular construction addressed and what the solutions were that could realize circular construction. Interviews were conducted until no new themes emerged (i.e., thematic saturation). Although interviews are not strictly necessary for a Q-methodology, they were used to enhance the validity of our concourse.

The second step aims to distil a manageable set of diverse statements that reflects the heterogeneity of the concourse – hereafter called the 'Q-set'. Deriving statements was done through inductive thematic analysis (Braun et al., 2019; Braun & Clarke, 2006). Transcripts were analysed using 'open coding' on the sentence level according to two themes: (1) the *problems* that circular construction aims to address, and (2) the *solutions* that could realize circular construction. For our coding rules we defined problems as "matters that cause one difficulty or need to be dealt with" and defined solutions as "*answers to* problems". Themes that emerged from 'axial coding' were collectively discussed to resolve any inter-coder disagreements and were each collectively translated into statements. Statements should be unique, clear, and brief. Overlapping statements were omitted or merged. All statements were shared with three stakeholders (i.e., two researchers and one practitioner) to test them for unambiguity. The thematic analysis resulted in forty-five statements, eighteen of which were problem-oriented and twenty-seven solution-oriented (Appendix 3.1).

The third step involves the selection of respondents – i.e., the P-sample. Because Q-methodology aims to reveal the *variety* of perspectives as opposed to reflecting the relative *importance* of perspectives, Q-methodology is usually done through purposive sampling with small sample sizes, as opposed to random sampling with large sample sizes (McKeown & Thomas, 1988). Typical sample sizes range from twenty to sixty respondents (Phi et al., 2014). Moreover, the diversity of respondents' worldviews is crucial for Q-methodology. Purposive sampling therefore aims to include respondents that reflect a broad range of views on a particular topic. These respondents are usually different from those who were interviewed for the concourse (step 1) to enhance the reliability of Q-methodology. To ensure a diverse P-sample, fifty-eight actors were invited by email to partake in this study, and chosen based on their actor type (e.g., industry) and sub-type (e.g., supplier) that they represent (Appendix 3.2). This resulted in thirty-four respondents.

The fourth step refers to the Q-sort. During the Q-sort, respondents ranked the statements on a Likert-scale according to their vision i.e., -5 to 5 in which -5 represented 'relatively agree with least' and 5 indicated 'relatively agree with most' (Figure 5). The ranking followed a normal distribution with few statements on each extreme. Q-sorts were digitally sorted and collected using qmethodsoftware.com, which is an online survey platform (Lutfallah & Buchanan, 2019). Respondents entered this survey by invitations via email. A Pearson correlation matrix of the thirty-four Q-sorts was created to yield an understanding of the P-sample's diversity. The mean Q-sort correlation is 0.29, suggesting a heterogeneous P-sample in terms of visions for the Dutch circular construction sector.

In the fifth step, a factor analysis is conducted to yield groups (i.e., factors) of highly correlating Q-sorts (i.e., rankings). For Q-methodology, the standard approach is a centroid factor analysis with a Varimax factor rotation (Watts & Stenner, 2005). Factors are typically included if they contain at least one unique factor loading, indicating that at least one respondent's perspective corresponds best with a factor. Furthermore, factors preferably meet both the Kaiser-Guttman criterion and Humphrey's rule.

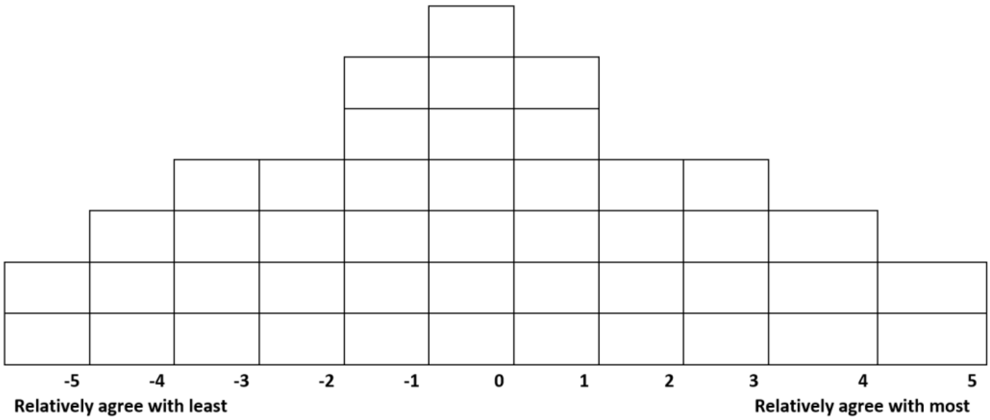

Figure 5. Q-sort distribution. Source: authors' own elaboration.

In this study, factors that emerge from the analysis represent imaginaries with which multiple respondents' visions correlate. We followed the approach described above and included factors with at least one unique factor loading of 0.385 or above, indicating a vision's correlation with a factor at the statistically significant level of $p < 0.01$ (Equation 1). This factor loading threshold was computed as follows (McKeown & Thomas, 1988):

$$Factor\ loading = 2.58 * SE = 2.58 * \frac{1}{\sqrt{N\ statements}} \qquad \text{(Equation 1)}$$

The factor analysis resulted in three factors (i.e., imaginaries), with which the visions of thirty respondents correlated significantly (Appendix 3.3). It must be noted that a respondent's vision can correlate significantly with multiple factors. To enhance the comprehensibility of the results, we grouped every respondent with the factor that the person correlated best with. 4 respondents did not load significantly on any factor. All factors satisfied both the Kaiser-Guttman criterion and Humphrey's rule. Appendices 3.3 and 3.4 provide the factor arrays and factor loadings, respectively.

In the sixth step, these factors are interpreted using several forms of data. The interpretation is largely based on the highest/lowest (+5,+4,-4,-5) and distinguishing statements (Tables 5, 6, and 7). Distinguishing statements are those that were Q-sorted differently, on the statistically significant level of p < 0.01, for one factor in comparison to the remaining factors (Coogan & Herrington, 2011; Rodhouse et al., 2021). The nature of statements that followed from step two further informs us about the orientation of factors (i.e., problem-oriented or solution-oriented). We also used the preliminary interview data to contextualize the factors and statement scores. Each factor represents an imaginary regarding the Dutch circular construction sector.

The analysis was extended by comparing these identified imaginaries with the government-constructed imaginary *'Circular construction by 2050'* (Section 3.3.1) as presented through various policy documents (e.g., BZK, 2019; IenW & EZK, 2016). These policy documents were subject to the same thematic analysis, as described in step two of this section, to understand the explicitly mentioned problem-oriented and solution-oriented views of the government.

3.4 Results

In what follows, Section 3.4 describes each imaginary that emerged from the Q-analysis. We have named these three imaginaries *We need to use fewer resources more efficiently; Let's reimagine design strategies;* and *Construction needs a mix of solutions.*

Imaginary 1: We need to use fewer resources more efficiently

Respondents who support this imaginary appear to have a defined idea of the problem (Table 5). Circular construction can help avoid resource depletion and contribute to a climate-neutral society. This imaginary disagrees most with the statements that circular construction will reduce the risk of water shortages and will benefit the water quality in the Netherlands. This imaginary unanimously agreed on the insignificance of circularity for social inequalities. In terms of solutions, it believes that circularity should be achieved through a reduction of primary resources. The actors unanimously agreed on the importance of using resources more efficiently. In addition, this imaginary supports a cradle-to-cradle approach and the minimization of material use. They furthermore doubt that blockchain or a change in asset ownership would effectively resolve the problems circular construction aims to address.

Seventeen respondents correlated significantly with this imaginary, of which thirteen corresponded best with it. Seven respondents correlated solely on this imaginary. The thirteen respondents consisted of actors from the category industry (N=2), construction clients (N=4), researchers (N=4), advisory firms (N=2), and infrastructure (N=1).

Table 5. Distinguishing (D) and most defining (+5,+4,-4,-5) statements of Imaginary 1.

Statements	*No.*	*Statement*
+5	5(P)	With circular construction, we avoid the depletion of our earth
+5 (D)	17(P)	Circular construction contributes to achieving a climate-neutral society
+4	23(S)	A reduction in the use of primary resources must be a priority for circular construction
+4	27(S)	Circular construction starts with thinking about how to use resources efficiently
+4 (D)	41(S)	Circular construction will need to focus more on the 'cradle-to-cradle' strategy
+3 (D)	37(S)	In circular initiatives, more focus is needed on sustainable materials
+2 (D)	32(S)	Future circular projects should focus on avoiding material use as much as possible
0 (D)	34(S)	Circular construction requires that assets are designed for disassembly
0 (D)	4(P)	Circular construction addresses the problem of waste production
0 (D)	6(P)	The problem of linear construction lies mainly in the use of primary resources
0 (D)	21(S)	Modular design is essential for circular construction
0 (D)	25(S)	Circular construction requires new monitoring and measurement systems that can be used to manage circularity
-1 (D)	13(P)	Circular construction can reduce the sector's energy consumption
-1 (D)	19(S)	In a circular construction, down cycling of materials is inevitable
-2 (D)	18(P)	Circular construction is primarily a means to reduce greenhouse gas emissions
-2 (D)	35(S)	Material passports are necessary to realize circular construction
-3 (D)	1(P)	Circular construction provides lower particulate emissions than linear construction
-3 (D)	40(S)	Climate adaptive building contributes to achieving circular construction
-3 (D)	30(S)	As-a-service business models play a key role in kick-starting the transition to circular construction
-4	15(P)	Circular construction contributes to reducing social inequalities in our society
-4 (D)	26(S)	In order to realize a circular construction, suppliers and contractors must ultimately become responsible for assets over their entire lifecycle
-4 (D)	42(S)	Block chain can play an important role in making circular construction a reality
-5	8(P)	Circular construction reduces the risk of water shortages in the Netherlands
-5	11(P)	Circular construction benefits the water quality of the Netherlands

Table 6. Distinguishing (D) and most defining (+5,+4,-4,-5) statements of Imaginary 2.

Statements	*No.*	*Statement*
+5 (D)	28(S)	Material and design strategies should focus on the highest possible R-strategy on the "R-ladder"
+5	5(P)	With circular construction, we avoid the depletion of our earth
+4	27(S)	Circular construction starts with thinking about how to use resources efficiently
+4	21(S)	Modular design is essential for circular construction
+4	34(S)	Circular construction requires that assets are designed for disassembly
+3 (D)	25(S)	Circular construction requires new monitoring and measurement systems that can be used to manage circularity
+3 (D)	17(P)	Circular construction contributes to achieving a climate-neutral society
+2 (D)	35(S)	Material passports are necessary to realize circular construction
+1 (D)	23(S)	A reduction in the use of primary resources must be a priority for circular construction
0 (D)	39(S)	Circular construction requires substantial changes in current laws and regulations
0 (D)	18(P)	Circular construction is primarily a means to reduce greenhouse gas emissions
-1 (D)	36(S)	New standards and guidelines are needed to facilitate circular construction
-1 (D)	1(P)	Circular construction provides lower particulate emissions than linear construction
-2 (D)	26(S)	In order to realize a circular construction, suppliers and contractors must ultimately become responsible for assets over their entire lifecycle
-2 (D)	6(P)	The problem of linear construction lies mainly in the use of primary resources
-3 (D)	8(P)	Circular construction reduces the risk of water shortages in the Netherlands
-3 (D)	33(S)	Circular construction should focus on reducing waste production
-3 (D)	7(P)	Circular construction is necessary to combat the decline of biodiversity
-4	11(P)	Circular construction benefits the water quality of the Netherlands
-4	15(P)	Circular construction contributes to reducing social inequalities in our society
-4 (D)	4(P)	Circular construction addresses the problem of waste production
-5 (D)	19(S)	In a circular construction, down cycling of materials is inevitable
-5 (D)	22(S)	The construction sector must focus on recycling to become circular

Imaginary 2: Let's reimagine design strategies

Imaginary 2 believes that circular construction helps address resource depletion and achieve a climate-neutral society, and comparatively disagrees that circular construction will combat water shortages, water pollution, social inequalities, and biodiversity loss (Table 6). The imaginary appears to fairly disagree that circular construction can and should prioritize waste reduction. In terms of solutions, this imaginary primarily focuses on design strategies.

While this group believes downcycling is avoidable, it is not a proponent of recycling as a solution pathway. Instead, design strategies should strive to move material flows as high as possible on the R-ladder (e.g., refuse, rethink, reuse, etc.). Although resource efficiency is deemed important, circular construction should also focus on modular designs and design-for-disassembly. The imaginary pleads for material passports, and new monitoring and measurement systems to provide insight into circularity.

Thirteen respondents correlated significantly, of which nine corresponded best with this imaginary. Six respondents correlated solely with this imaginary. The nine respondents consisted of actors from the category industry (N=1), construction clients (N=3), policy (N=1), researchers (N=2), advisory firms (N=1), and infrastructure (N=1).

Imaginary 3: Construction needs a mix of solutions

According to Imaginary 3, the central problem that circular construction tackles is the overuse of primary resources to prevent resource depletion (Table 7). It relatively disagrees that circular construction could reduce greenhouse gasses and particle emissions. Furthermore, it seems comparatively unconvinced of the potential benefits of circularity in relation to water shortages, water pollution, biodiversity loss, and social inequalities. What sets Imaginary 3 apart from the other imaginaries is its strong support for a mix of solutions. It advocates material passports, and new monitoring and measurement systems to manage circularity. It also implores changes in procurement strategies and living standards. Imaginary 3 supports novel design strategies such as modular design and design-for-disassembly. A number of these solutions focus on facilitating circularity.

Twelve respondents correlated significantly, of which eight corresponded best with this imaginary. Five respondents correlated solely with this imaginary. The eight respondents consisted of actors from the category industry (N=1), construction clients (N=5), and advisory firms (N=2). Noteworthy is that nearly half of all actors falling in the category construction clients correlate statistically significantly with this imaginary (six out of thirteen).

Table 7. Distinguishing (D) and most defining (+5,+4,-4,-5) statements of Imaginary 3.

Statements	*No.*	*Statement*
+5 (D)	25(S)	Circular construction requires new monitoring and measurement systems that can be used to manage circularity
+5	23(S)	A reduction in the use of primary resources must be a priority for circular construction
+4	34(S)	Circular construction requires that assets are designed for disassembly
+4	21(S)	Modular design is essential for circular construction
+4 (D)	44(S)	Procurement strategies are essential tools for achieving circular assets
+3 (D)	35(S)	Material passports are necessary to realize circular construction
+1 (D)	6(P)	The problem of linear construction lies mainly in the use of primary resources
+1 (D)	45(S)	Reducing the material demand requires changes in our lives, for example by living smaller
+1 (D)	16(P)	With circular construction, the industry’s supply risks of materials and components can be decreased
-1 (D)	31(S)	A carbon tax is a crucial measure to accelerate the transition to a circular construction sector
-1 (D)	2(P)	One of the goals of circularity in the construction industry is to reduce greenhouse gas emissions
-1 (D)	14(P)	The core problem that circular construction addresses is environmental impact and climate change
-2 (D)	17(P)	Circular construction contributes to achieving a climate-neutral society
-2 (D)	4(P)	Circular construction addresses the problem of waste production
-3 (D)	12(P)	Circular construction can prevent health damage by better handling toxic materials
-3 (D)	19(S)	In a circular construction, down cycling of materials is inevitable
-3 (D)	20(S)	Circular construction requires that a large portion of the materials used be bio-based
-3 (D)	26(S)	In order to realize a circular construction, suppliers and contractors must ultimately become responsible for assets over their entire lifecycle
-4	11(P)	Circular construction benefits the water quality of the Netherlands
-4 (D)	1(P)	Circular construction provides lower particulate emissions than linear construction
-4 (D)	18(P)	Circular construction is primarily a means to reduce greenhouse gas emissions
-5	15(P)	Circular construction contributes to reducing social inequalities in our society
-5	8(P)	Circular construction reduces the risk of water shortages in the Netherlands

3.5 Comparing imaginaries

Section 3.5.1 proceeds by comparing the three identified imaginaries based on their highest/lowest statements to understand contestation. Section 5.2 follows by comparing these three identified imaginaries with the government-constructed imaginary *'Circular construction by 2050'*.

3.5.1 Comparing identified imaginaries

This section compares the three imaginaries to understand their differences and similarities. Table 8 provides a correlation matrix of the three imaginaries. Both the correlation matrix and the descriptions above suggest room for common ground as they share various normative ideas. For example, all imaginaries agree that circular construction could address the problem of resource depletion of (primary) resources by increasing efficiency. All imaginaries seem to relatively disagree with the idea that asset ownership should be shifted from public organizations to suppliers and contractors. In addition, all imaginaries seem to disagree that circular construction addresses water pollution, water shortages, and social inequalities. Hence, all imaginaries seem sceptical about some potential socio-environmental benefits of circular construction. The mean Likert-scale ranking of the problem-oriented statements and solution-oriented statements (Table 9) suggests furthermore that Imaginary 3 *'Construction needs a mix of solutions'* agrees more with the solution statements and less with the problem statements than the other imaginaries.

Table 8. Pearson correlation matrix between imaginaries.

	Imaginary 1	*Imaginary 2*	*Imaginary 3*
Imaginary 1	1.00	0.60	0.57
Imaginary 2	0.60	1.00	0.65
Imaginary 3	0.57	0.65	1.00

Table 9. Mean ranking problem-oriented and solution-oriented statements per imaginary.

	Mean ranking problem-oriented statements	*Mean ranking solution-oriented statements*
Imaginary 1	-0.61	0.41
Imaginary 2	-0.61	0.41
Imaginary 3	-1.50	1.00

Imaginary 2 *'Let's reimagine design strategies'* and Imaginary 3 *'Construction needs a mix of solutions'* are most similar (r = 0.65). Actors from both these groups tend to support modular designs, design-for-disassembly, material passports, and new monitoring and measurement systems. They believe that down cycling is preventable. However, these imaginaries relatively disagree on the importance of circular construction for climate neutrality. Imaginary 3 furthermore disagrees that circular construction reduces greenhouse gas and particulate emissions. Imaginary 2 also differs from Imaginary 3 in the sense that Imaginary 3 appears less confident about the problems that circular construction addresses.

Imaginary 1 *'We need to use fewer resources more efficiently'* and Imaginary 2 *'Let's reimagine design strategies'* (r = 0.60) both believe that circular construction will contribute to climate neutrality, and that it must prioritize efficient resource use. Yet, Imaginary 2 seems to be a greater proponent of closed systems while Imaginary 1 emphasizes the reduction of material flows.

Imaginary 1 *'We need to use fewer resources more efficiently'* and Imaginary 3 *'Construction needs a mix of solutions'* are the least similar imaginaries (r = 0.57). Both imaginaries relatively disagree with the idea that suppliers and contractors should be responsible for assets throughout their lifecycle. These two imaginaries also believe that circular construction will not lower greenhouse gas emissions and particulate emissions. While Imaginary 3 predominantly focuses on solutions, Imaginary 1 demonstrates a more balanced view, focusing on both problems and solutions. Imaginary 3 supports a plurality of solutions, advocating modular designs, design-for-disassembly, novel procurement strategies, material passports, and new monitoring and measurement systems. Imaginary 1 signifies a narrower solution space, prioritizing efficient resource use, sustainable material, and cradle-to-cradle strategies.

Lastly, the actor types from our P-sample appear fairly evenly distributed among imaginaries (Table 10). The only actor type that is disproportionally distributed is researchers. Most researchers are adherents of the first (N=4) and second imaginary (N=2), but none support the third imaginary (N=0). This suggests that the normative visions of circular construction are largely independent of the actor type. Note that actors with non-significant loadings are not included in the table.

Table 10. Number of actors with the highest significant loading per imaginary.

	Industry	*Construction clients*	*Policy*	*Resear-chers*	*Advisory firms*	*Infrastructure*	*Total*
Imaginary 1	2 (40%)	4 (33%)	0 (0%)	4 (67%)	2 (40%)	1 (50%)	13 (38%)
Imaginary 2	1 (20%)	3 (25%)	1 (100%)	2 (33%)	1 (20%)	1 (50%)	9 (26%)
Imaginary 3	1 (20%)	5 (42%)	0 (0%	0 (0%)	2 (40%)	0 (0%)	8 (24%)
Total	5 (100%)	12 (100%)	1 (100%)	6 (100%)	5 (100%)	2 (100%)	30 (100%)

3.5.2 Comparing identified imaginaries with the formal policy imaginary

Our results indicate that the three imaginaries differ in the extent to which they acknowledge and favour certain problems and solutions. These imaginaries coexist with the imaginary '*Circular construction by 2050'* as constructed by the Dutch government, and actualized through its formal policy (BZK, 2019; IenW & EZK, 2016). While it is increasingly recognized that imaginaries may clash (Burnham et al., 2017; Hess, 2015), we identify and describe the problems/solutions that various imaginaries disagree on. We furthermore reveal spaces for common ground that could foster a collective response. These differences and commonalities inform us about how policymakers can possibly move forward.

When focusing on common grounds, all three identified imaginaries seem to agree with the '*Circular construction by 2050'* imaginary that circular construction could address the depletion of (primary) resources by focusing on their efficient use. Similar to the three identified imaginaries, the *'Circular construction by 2050'* imaginary does not target water pollution, water shortages, and social inequality. This opposes several perspectives derived from the concourse interviews (Section 3.3.2, step 1). Especially one interviewee from the Dutch Union of Water Boards envisioned that circular construction would result in these benefits. However, our results suggest that this vision is not widely shared. The *'Circular construction by 2050'* furthermore stresses the importance of both material passports and new measurement and monitoring systems. While this vision resonates with that of Imaginaries 2 and 3, it is considered less important in Imaginary 1.

In terms of contestation, Imaginaries 1 and 3 both seem sceptical that circular construction will lower greenhouse gas emissions. This fundamentally contradicts the *'Circular construction by 2050'* imaginary in which CO_2 reduction forms one of the main rationales for circular construction (BZK, 2019; IenW & EZK, 2016). In addition, a very clear solution priority for Imaginaries 2 and 3 – and to a lesser extent for Imaginary 1 – is the use of modular designs and design-for-disassembly. Yet, this is hardly mentioned by the strategy reports that delineate the government's imaginary. The *'Circular construction by 2050'* imaginary also pleads for more regulation and standardization of circular construction, but the other imaginaries seem less outspoken about such approaches. The same can be argued for climate adaptive approaches to construction. While the government supports this solution pathway, other imaginaries are less outspoken about it.

Hence, the results indicate that there is not merely disagreement among the three identified imaginaries, but also between these and the *'Circular construction by 2050'* imaginary. Regardless of the *de facto* existence and severity of the sector's CO_2 emissions, it seems unlikely that actors from the three identified imaginaries will be mobilized by this framing. Policymakers could, on the contrary, gain support from the three imaginaries by incorporating modular designs and design-for-disassembly as solution strategies. Policymakers could reframe problems/solutions accordingly to redirect patterns of innovation in response to the societal challenges.

3.6 Discussion

In what follows, Section 3.6.1 reflects on the implications of this chapter. Section 3.6.2 proceeds by discussing how policymakers can navigate contested problem-solution spaces, and thus offers ways forward. Section 3.6.3 expands on some limitations and opportunities for future research, which is followed by concluding remarks in Section 6.4.

3.6.1 Operationalizing problem-solution spaces with Q-methodology

This chapter demonstrates how contestation in the problem-solution space can be operationalized through Q-methodology using various types of sources; by combining and comparing data of interviews, a survey, and policy documents. Accordingly, we illustrate how divergent imaginaries can be identified, described, and compared to understand the way and extent to which challenges are contested. Although Q-methodology has been used to understand contestation before (e.g., Cuppen et al., 2010; Gruszka, 2017; Ligtvoet et al., 2016; Rodhouse et al., 2021), our contribution lies in offering a systematic approach to deconstruct contestation in terms of problem-oriented and solution-oriented disagreement. By differentiating these two spaces, researchers and practitioners can scrutinize one of these two parts further. In our illustrative case, for instance, the mean rankings (Table 9) indicate that the Dutch circular construction sector is more convergent in the solution space than in the problem space – particularly in Imaginary 3. This suggests circular construction to be a "solution in search of a problem" (Wanzenböck et al., 2020, p. 478). Actors could subsequently examine in more depth why the problem space is contested (e.g., information asymmetries or incompatible value systems) so that actors can further consolidate a shared understanding of circular construction's problem space. The operationalization of this paper thus helps advance research on problem-solution spaces, and helps actors analyse and navigate the contestation of any given societal challenge.

3.6.2 Policy implications: navigating contestation

The operationalization of the problem-solution space by means of Q-methodology has various implications for policy. Because policymakers increasingly deploy challenge-led policies to create shared understandings and mobilize stakeholders into a uniform direction (Hekkert et al., 2020; Mazzucato, 2017, 2018a), learning from diverse and conflicting worldviews is necessary to avoid transformational failures (Schot & Steinmueller, 2018b; Weber & Rohracher, 2012). Without a reflexive governance (Voß & Bornemann, 2011), policymakers may acquire the false impression that views on problems and solutions are widely shared (Wanzenböck et al., 2020). The operationalization of the problem-solution space is not merely a reflexive exercise for policymakers, but it also stimulates participants of the Q-study to reflect on problems and potential solutions that could be taken for granted.

Disagreement prompts the question of how contestation should be navigated. We argue that our reflexive exercise contributes to *constructive approaches* (Cuppen, 2012; Ligtvoet et al., 2016) by yielding insights that could enhance mutual understanding necessary to find common ground, establish compromises, or reframe problems and solutions. In our case, such an approach could lead to more support for modular designs and design-for-disassembly. While this is promising, mutual understanding is insufficient for overcoming disagreements that are rooted in fundamentally incompatible values and worldviews (Blok & Lemmens, 2015; Schon & Rein, 1994). Impasses are preferably avoided as not acting may be seen as the prioritization of one imaginary over the other. What is more, reflexivity on the normative divergence in the problem-solution space does not necessarily inform policymakers about the epistemological nature of problems and solutions (e.g., what solutions are *de facto* effective?). For example, stakeholders can disagree about the necessary 'radicality' of solution pathways. While some transformations require *small wins* and/or short-term solutions, others would benefit from radical and/or long-term ones (Bours et al., 2021; Termeer & Dewulf, 2019). A default approach for policymakers is to rely on evidence-based visions of scientific experts. Yet, this is problematic for the reason that researchers can likewise hold divergent views as we show in our illustrative case. In addition, the input of other actors should not be disregarded because they have a qualitatively different, but complementary, expertise through experience. Such *experts by experience* are confronted with the problem, and are crucial for the implementation of solutions (Wanzenböck & Frenken, 2020). When contestation is rooted in incompatible values and worldviews, and exacerbated by epistemic uncertainty, policymaking tends to be highly problematic.

To deal with this, scholars recently suggested that *agonistic approaches* may offer a way out. According to this approach, decisions are made while recognizing that fundamental disagreements are inevitable (Popa et al., 2021; Scott, 2021). In practice this means that policymakers need to make difficult decisions while acknowledging opposing imaginaries as rational (Mouffe, 2000).

In our particular case, the three imaginaries could fundamentally disagree on whether CO_2 emissions are problematic. An *agonistic approach* could then be to accept this worldview's incompatibility with the *imaginary 'Circular construction by 2050'* but still demand a reduction of CO_2 emissions on epistemological grounds. The operationalization of the problem-solution space through Q-methodology is instrumental to revealing the source of disagreement, and thus helps understand whether a *constructive* or *agonistic approach* is more suitable.

3.6.3 Limitations and future research

We demonstrate an operationalization of the problem-solution space by means of Q-methodology. While Q-methodology is a broadly accepted research method that has existed already for nearly a century, it is important to stress a number of limitations (Brown, 1992; Stephenson, 1935). First, Q-methodology relies on statements that usually emerge from thematic analyses. While thematic analysis is a useful research method for identifying key aspects of large data sets, its methodological flexibility can lead to inconsistencies that affect the reproducibility of themes – in our case the problem and solution-oriented statements (Nowell et al., 2017). This is especially relevant for wicked problems research in which problem framings and solution framings interact in the sense that the framing of one may suggest the framing of the other. Furthermore, one should be aware of potential biases that emerged from the sampling strategies. Although we aimed to include actors across all actor types in our P-sample, no civil society organization was willing to partake in this study. Our results therefore hint that our mission-specific innovation system is distinct from many other systems in the sense that societal stakeholders have relatively little interest in its mission. Second, statistical studies of qualitative materials tend to treat quantitative results as 'real'. They are often objectified and reified. We would like to stress that our results and the underlying data (i.e., interviews, survey, and policy documents) are constructs. Our study may therefore come with epistemological limitations. For instance, notions like 'circular construction' may suffer from interpretative flexibility (Pinch & Bijker, 1984). Results should therefore be treated with caution.

Our study offers various avenues for future research. First, it examined contestation in a problem-solution space by identifying, describing, and comparing underlying conflicting imaginaries by using Q-methodology. Although this method is useful for identifying the variety of imaginaries, it does not yield an understanding of their ubiquity. A promising continuation of our operationalization would be to conduct large scale surveys that aim to understand the generalizability of imaginaries that were identified. Second, while Jasanoff and Kim (2009) argue that collectively held visions help understand socio-technical developments, our results suggest that various actors who hold power and agency have distinct visions that do not fit in dominant imaginaries. Considering the performative nature of these uncommon visions, future research could study such outliers when exploring futures. Third, both a strength and limitation of the problem-solution space is that it reduces the complex phenomenon of contestation to perspectives on problems and solutions. While this simplification provides an initial understanding of contestation, problem-solution spaces are situated in a wider socio-technical and path-dependent system in which worldviews are driven by underlying values. It would be valuable to examine these broader contexts, historical dimensions, and value systems from which imaginaries emerge. For example, a better appreciation of the values at play would help understand whether either *constructive* or *agonistic approaches* are more appropriate. Fourth, this study provides a snapshot of a contested problem-solution space. Yet, imaginaries change over time. Capturing their temporal nature would therefore provide insight into the dynamics of imaginaries and societal challenges. We speculate, for example, that imaginaries may either drift apart or move closer to each other – causing polarization or unification. Apart from gaining a deeper understanding, such an approach would provide useful insights for developing policy instruments aimed at problem-solution convergence. Fifth, our operationalization is applied to the circular construction sector. Future applications of other problem-solution spaces would provide more insight into the usefulness of the approach.

3.6.4 Concluding remarks

This study contributes to the literature on problem-solution spaces and reflexive governance by offering an operationalization that identifies, describes, and compares conflicting imaginaries of wicked problems and potential solutions by means of Q-methodology. To demonstrate this operationalization, we applied the approach to the case of the Dutch circular construction and identified divergent imaginaries that coexist with the government-constructed imaginary *'Circular construction by 2050'.* This study identified three imaginaries that help us understand contestation. We named these imaginaries (1) '*We need to use less resources more efficiently',* (2) *'Let's reimagine design strategies'*, and (3) *'Construction needs a mix of solutions'.* We revealed various (dis)agreements between the imaginaries and diagnosed circular construction as a 'solution in search of a problem'. Operationalizing contested problem-solution spaces prompts the question of how to navigate disagreement. This chapter discusses how *constructive* and *agonistic approaches* may offer ways forward to shape a collective response. While this study explores and links the notions of imaginaries, contestation, and problem-solution spaces, we advocate future research that helps us further understand how to arrive at a shared understanding of both societal problems and their required solutions. This would help actors more effectively address the societal challenges of our time.

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chapter 4

mission-oriented transition assessment: the case of circular infrastructure

Abstract: The recent mission-oriented discourse in innovation policy requires participatory, anticipatory, reflexive, and tentative governance modes to address the wickedness associated with societal challenges. In this chapter, we introduce Mission-Oriented Transition Assessment (MOTA) as a novel approach to collectively anticipate and reflect upon current and future mission-oriented transition dynamics. Using socio-technical scenarios, MOTA is used to appraise current and future developments and inform stakeholders, particularly policymakers, on how to govern missions. Stakeholders are stimulated to reflect on their role in transitions to collectively find ways to overcome transition barriers and to address tensions between the current and future socio-technical systems. In this chapter, MOTA is demonstrated using the Dutch mission 'Circular infrastructure by 2050'. Results indicate how MOTA contributes to increasing social robustness, preparedness, awareness, and alignment between the stakeholders in the transition towards a circular infrastructure sector. As such, it provides valuable strategic and actionable insights toward addressing societal challenges, as well as an understanding of the mission barriers.

This chapter was written by T.B.J. Coenen, M.J. Wiarda, K. Visscher, C.C.R. Penna, and L. Volker and is at time of publishing the dissertation under review in a scientific journal.

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4.1 Introduction

Inspired by major endeavours in the twentieth century, contemporary science, technology, and innovation policies have become increasingly challenge-led, particularly in Europe (Brown, 2021; Janssen, 2020; Kuittinen & Velte, 2018). Dominant economic growth-oriented policies are unable to resolve these challenges (Schot & Steinmueller, 2018b). There is an increasing shift toward challenge-led approaches that are designed to promote sustainable development (Kuhlmann & Rip, 2018), of which the uptake of mission-oriented efforts by the European Commission is a recent example (Mazzucato, 2018b). Mission-oriented Innovation Policies (MIP) are primarily aimed at mobilizing stakeholders and providing the conditions for socio-technical change in a largely predefined direction (Mazzucato et al., 2020; Schot & Steinmueller, 2018b). In this context, missions can be understood as “boundary objects around which heterogeneous communities […] gather and craft together shared understandings of what is at stake, what means are necessary, and what processes should ensue” (Janssen et al., 2023, p.2). MIPs have the potential to instigate complex, open-ended, non-linear, and long-term transitions that are difficult to plan, predict, and manage (Hekkert et al., 2020; Köhler et al., 2019). These transitions involve multiple actors, dimensions, and levels (Grin et al., 2010) and suit the systemic nature of today’s socio-technical challenges.

While the body of literature on the formulation and design of missions and MIPs is growing, hardly any studies address the process of implementing these (Janssen et al., 2021). The complexity and uncertainty involved in addressing such missions require governance approaches that are reflexive and anticipatory (Rosa et al., 2021) to arrive at suitable policies and policy implementation processes. Currently, several reflexive and anticipatory approaches exist that incorporate elements of reflexivity and anticipation (Van Lente et al., 2017). Missions, however, address a myriad of systemic changes across multiple dimensions and aim to offer a converging directionality of socio-technical change (Wanzenböck et al., 2020). Consequently, there is a need for approaches that support policymakers in mission governance, while having and using such normative and substantive approaches is crucial for the social construction of early-stage transitions (Pallett & Chilvers, 2013).

In this chapter, we address the question of how to govern mission-oriented transitions through reflexive and anticipatory deliberations by linking existing approaches of reflexive and anticipatory governance for innovation with the mission-oriented policy literature. We refer to this governance approach as Mission-Oriented Transition Assessment (MOTA), defining it as a collective appraisal of current and future socio-technical changes to inform stakeholders, particularly policymakers, on how to govern missions. This enables decision-makers to reflect on the governance of mission-oriented transitions as a tentative form of governance, providing for greater responsiveness to heterogeneous stakeholder values and worldviews (Kuhlmann et al., 2019; Stilgoe et al., 2013). The purpose of this chapter is to theoretically and conceptually develop, empirically demonstrate, and appraise MOTA by applying it to the case of the Dutch infrastructure sector launching a mission to transition toward the circular economy (CE).

The remainder of the chapter is structured as follows. The theoretical governance framework for MOTA is introduced in Section 4.2, reflecting on the governance challenges, responsibilities, modes, and forms of success associated with MIPs for wicked problems. This basis is used to conceptualize MOTA in Section 4.3. Section 4.4 discusses the research approach to our case study, after which we report the results in Section 4.5. In Section 4.6 we discuss some implications on both the framework and the case application and Section 4.7 concludes the chapter and offers directions for further research.

4.2 Theoretical background

4.2.1 Transitions in the context of missions and societal challenges

MIPs are focused on achieving specific societal goals within a predefined timeframe through cross-sectoral innovation, differentiating them as transformer missions from earlier accelerator missions (Wittmann et al., 2021). Accelerator missions generally sought to achieve technological feats (Soete & Arundel, 1995; Wittmann et al., 2021), such as putting humans on the moon and returning them safely to Earth (Apollo Program's mission) or developing an atomic bomb (Manhattan Project´s mission). Contrary to these relatively insulated and technology-focused missions, recent missions are generally aimed at tackling so-called wicked problems and driving transformative change (Mazzucato, 2022), such as the transition towards climate-neutral cities, the transition towards the CE, achieving gender equality, or the elimination of cancer. Here, it is often not technology that poses the central challenges to transitioning, but the socio-institutional dynamics within the system (Truffer et al., 2017), which can be introduced from supranational to regional scales.

Because of their focus beyond technology, contemporary MIPs are mainly advanced as a way to mitigate transformative system failures – particularly directionality failures (Weber & Rohracher, 2012) – and to promote radical changes that address urgent societal challenges. Accordingly, Hekkert et al. (2020) defined the contemporary generation of MIP as "an urgent strategic goal that requires transformative systems change [or a transition] directed towards overcoming a wicked societal problem" (p.76). Hence, we understand wickedness as embodying high degrees of complexity, uncertainty, and contestation (Head, 2008; Rittel & Webber, 1973; Wanzenböck et al., 2020). The degree and interaction of these three dimensions indicate to what extent problems are wicked (Alford & Head, 2017). Moreover, a mission orientation generally leans on the notion that socio-technical change is characterized by accumulation and directionality (Dosi, 1982; Kuhn, 1962), and recognizes that a redirection of socio-technical systems requires the explicit selection of problems and solutions (Bugge & Fevolden, 2019; Hekkert et al., 2020).

From a governance perspective, MIPs are unique in the sense that they promise to unite stakeholders behind a commonly recognized goal (Janssen et al., 2021). Because of the complexities and uncertainties involved, this entails significant governance challenges about purposive transition processes. Various conceptualizations of MIP types have been introduced (c.f., Diercks et al., 2019; Wanzenböck et al., 2020; Wittmann et al., 2021) to promote effective governance of systemic transformations. The more ambitious and transformative the policy, the higher the level of coordination required to make ongoing changes compatible with each other (Wittmann et al., 2021). Unfortunately, conventional roadmaps that technically preselect innovation pathways based on an innovation's transformative potential (e.g., Miedzinski et al., 2019) tend to miss the wickedness of the societal challenge being addressed. Yet, it is this wickedness of societal problems and potential solutions that poses substantial governance challenges that call for dedicated governance approaches (Wanzenböck et al., 2020).

While MIP literature has studied the upstream phase of establishing missions (e.g., Mazzucato et al., 2020; Rosa et al., 2021), it has largely overlooked the midstream processes of governing and implementing them (Janssen et al., 2021). This disregard is for example apparent in recent mission-oriented initiatives in Europe (cf., Larrue, 2021), where the implementation of societal missions on various levels requires new forms of governance and collaboration (EC & DGRI, 2023). Therefore, we need a governance framework that embraces this wickedness that is generally considered irreducible (Rittel & Webber, 1973), for which we first need to determine the major challenges in governing missions.

4.2.2 Governance challenges to missions from a wickedness perspective

Since the societal challenges addressed by MIPs are highly wicked, the missions, and more specifically MIPs, need to cope with c*omplexity*, *uncertainty*, and *contestation.* These three dimensions pose substantial governance challenges to policymakers because they cause resistance to change and resolution – i.e., *intractability* (Campbell, 2003; Head, 2022). In the remainder of the section, the governance challenges and their implications for the development of a governance framework suitable to address mission-oriented transitions are linked to governance modes that address the wickedness dimensions.

Complexity

Complexity stems from the multi-actor, multi-dimensional, multi-scalar, and constantly changing nature of societal challenges (Wanzenböck et al., 2020; Wiarda & Doorn, 2023). Rittel and Webber (1973, p. 161) argued that: “the information needed to understand the problems depends upon one’s idea for solving it. That is to say: in order to describe a wicked problem in sufficient detail, one has to develop an exhaustive inventory of all conceivable solutions ahead of time”. This is a major reason why the complexity dimension is generally irreducible and hence imposes a knowledge deficiency on decision-makers (Stirling, 2008). Inclusive approaches are needed to deal with the complexity that leverages the knowledge, moral judgment, and agency that is distributed among stakeholders (Head, 2008; Klerkx & Rose, 2020; Wanzenböck et al., 2020).

Inclusion may be achieved through participatory governance modes (Newig & Fritsch, 2009), which allow for the early identification of the values and worldviews of stakeholders (Bauer et al., 2021). Participatory governance commonly requires engagement through shared spaces in the shape of, e.g., hybrid forums (Callon et al., 2009) or arenas (Loorbach, 2010; Wesseling & Meijerhof, 2023), ideally facilitating mutual learning using consultation and participation (Rowe & Frewer, 2005). While stakeholders involved will not replace policymakers, researchers, and innovators, they would rather ground those policymakers firmer into the real world (Harremoës et al., 2001). As such, participatory governance plays an important role in the social construction of technology (Pinch & Bijker, 1984) to create more socially robust mission-oriented transition outcomes (Nowotny, 2003).

Uncertainty

Governance challenges related to wicked societal challenges are also associated with epistemic and normative uncertainty (Head, 2008; Wanzenböck et al., 2020). Epistemic uncertainty stems from the notion that decision-makers are faced with unknowns, for instance regarding the occurrence of particular events, their likelihood, or their severity (Hoffmann-Riem & Wynne, 2002). Normative uncertainty arises as “there is not one unequivocal right or wrong answer to an ethical question regarding risk – along with scientific and technical uncertainty” (Taebi et al., 2020, p. 2). An example of normative and epistemic uncertainty is that of economic uncertainty related to whether solutions will be economically viable or socially acceptable. Because epistemic and normative uncertainty are strongly linked to the desirability of innovations or socio-technical changes, these types of uncertainty may give rise to demand articulation failures (Weber & Rohracher, 2012).

Anticipatory governance modes are arguably designed to deal with the uncertainties involved (Barben et al., 2007; Stilgoe et al., 2013). Anticipatory governance has been defined as “governing in the present to adapt to or shape uncertain futures” (Muiderman et al., 2020, p. 1) and goes beyond traditional risk-based governance by embracing uncertainties and unknowns (Hoffmann-Riem & Wynne, 2002; Stirling, 2010). Such forms of anticipation help us prepare for plausible mission outcomes. While anticipatory governance does not deal with the unknown future, it does prepare for the diverse potential transition pathways. Moreover, this governance mode calls for collectively defining the ‘right’ impacts and directionality (Shove & Walker, 2007; Von Schomberg, 2014), even though stakeholders may hold opposing views regarding the future (Muiderman et al., 2020).

Contestation

Contestation arises as a result of opposing values and worldviews carried by stakeholders (Wanzenböck et al., 2020). Wicked problems and possible solutions are contested because there are numerous ways of explaining, prioritizing, and addressing them (Rittel & Webber, 1973). Particularly because of the directional character of mission-oriented transitions, this contestation can be problematic. For example, circularity in Dutch construction was perceived in fundamentally different ways throughout the sector, which blurs the direction of socio-technical change (Wiarda et al., 2023). While a specific configuration of solutions concerning a societal challenge may satisfy one stakeholder, it may not do so for others (Pesch & Vermaas, 2020). The wickedness of societal challenges and related missions is often maintained by the notion that certain forms of contestation are irreconcilable as they are rooted in fundamental disagreements (Popa et al., 2021; Scott, 2021). If left unattended, contestation could lead to reflexivity failures, when actors fail to critically reflect on and adapt to other actors’ values and interests (Weber & Rohracher, 2012; Wesseling & Meijerhof, 2023).

Contestation can be addressed by forms of reflexive governance (Voß & Bornemann, 2011). Reflexivity is crucial for collective sensemaking (Garud & Gehman, 2012) because policymakers do not always “know best” or “act best” in understanding problems and proposed solutions (Kirchherr et al., 2023, p. 4). Preventing reflexivity failures therefore strongly relates to the awareness of diverging and evolving problem understandings and alternative solution pathways (Weber & Rohracher, 2012; Wesseling & Meijerhof, 2023). Reflexivity acts as 'holding up a mirror' to reflect on how stakeholders' worldviews and value systems shape the activities, assumptions, and commitments of their institutional practices (Stilgoe et al., 2013). First- and second-order reflexivity can be distinguished where the former refers to forms of learning that take place "within boundaries of a value system and background theories" (van de Poel & Zwart, 2010. p. 180). In the context of missions, this relates to how predefined missions may be achieved best considering the prevailing or mainstream value system. In second-order reflexivity, however, the background theories and value system become an object of reflection. Reflexivity may hence lead to more effective and desirable reformulations and adaptions of missions and strategies as values and theories evolve.

4.2.3 The mission governance framework

Mission governance, thus, needs elements from participatory, anticipatory, and reflexive governance modes. Resultingly, a mission governance approach must facilitate decision-makers, including policymakers, with novel forms of reflexive and anticipatory deliberations that enable them to assess current and future socio-technical changes needed to promote transitions and thus achieve missions. In the remainder of this section, we will develop the theoretical governance framework that is used to construct the MOTA governance approach.

Such an approach should strive to help stakeholders identify opportunities to overcome transition barriers, recognize and address tensions between the current and desired system, and make decisions that take into account the values and worldviews of stakeholders. These three modes provide insights that could help decision-makers deal with the so-called Collingridge dilemma associated with uncertain transition outcomes (Collingridge, 1980; Lindner et al., 2016). This dilemma addresses how decision-making around innovation is problematized by the uncertainty in the early stages of technology and the rigidity that arises when it becomes entrenched in society, highlighting how both epistemic and normative uncertainty in the upstream developmental phases of innovation create problems for the societal construction of technology. When governing missions, stakeholder values and worldviews should therefore be considered before transitions materialize and cause new lock-ins (Arthur, 1989), entrenchments (Collingridge, 1980), and path-dependencies (David, 1995).

However, merely yielding knowledge insights is not enough to deal with wickedness, since policymakers are urged to unfold "a never-ending discourse with reality, to discover yet more facets, more dimensions of action, more opportunities for improvement" (Dery, 1984, p.6-7). Procedural approaches are thus needed to manage, cope with, and resolve the intractability of wicked problems (Head & Xiang, 2016; Xiang, 2013). Therefore, in responding to inclusive, anticipatory, and reflexive governance modes discussed in Section 4.2.2, mission governance requires a continuous form of responsiveness to challenges in mission-oriented transitions. Only then can it obtain "a capacity to change shape or direction in response to stakeholder and public values and changing circumstances" (Stilgoe et al., 2013, p.1572). Particular tentative governance is considered appropriate to mobilize stakeholders and create alignment between the stakeholders concerning the mission and the solution pathways regarding the mission (Folke et al., 2005; Ison et al., 2014). A mission governance framework should contain, next to elements of the participatory, anticipatory, and reflexive governance resulting from the wickedness elements, the elements of tentative governance. A combination of these four governance modes is proposed to increase preparedness, social robustness, awareness, and alignment concerning the mission-oriented transition (Table 11). An important note is that these governance modes are not necessarily mutually exclusive and existing governance approaches often address elements of multiple modes.

Table 11. Mission governance framework: challenges, responsibilities, modes, and outcomes.

Mission governance framework

Challenges	*Responsibilities*	*Modes*	*Outcomes*
Complexity	Inclusion	Participatory governance	Social robustness
Uncertainty	Anticipation	Anticipatory governance	Preparedness
Contestation	Reflexivity	Reflexive governance	Awareness
Intractability	Responsiveness	Tentative governance	Alignment

4.2.4 Existing approaches relevant to supporting mission governance

Several existing approaches embody elements of anticipatory, participatory, reflexive, and tentative governance. These approaches are frequently placed under umbrella terms such as Responsible (Research and) Innovation (Stilgoe et al., 2013; Von Schomberg, 2013), Constructive and Real-Time Technology Assessment (Guston & Sarewitz, 2002; Schot & Rip, 1997), and Ethical and Legal and Social Aspects/Implications research (Fisher, 2005). Although the differences between the existing approaches are broadly appraised (e.g., Ryan & Blok, 2023; Van Lente et al., 2017; Zwart et al., 2014), they share the commonality of proactively exploring both normative and epistemic considerations through inclusive deliberations to mitigate possible risks and foster the social desirability of research and innovation (Ryan & Blok, 2023; Wiarda et al., 2021).

While the abovementioned umbrella terms witnessed an uptake in research and innovation, their focus primarily lies on emerging – often single – innovations rather than transitions as a whole. This is an important difference, because many heated societal debates relate to large-scale transitions comprising complex configurations of solutions instead of single innovations, especially when taking a mission-oriented perspective. An example of such societal debate is CE, in which specific configurations of technologies and related changes in socio-institutional aspects are needed for different contexts to close resource loops as effectively as possible (Velenturf & Purnell, 2021).

Particularly the stream of Technology Assessment (TA) is increasingly used as a structured and collective deliberation process as well as an approach to reflect on the many perspectives on the future regarding specific issue fields (Kuk et al., 2023). Truffer et al. (2017) showed that technology is not central to TA approaches but rather the social and institutional contexts that interact with these technologies. An alternative approach, which does focus on transitions at large, is Sustainability Foresight, which is a method to explore and appraise various future states of a socio-technical system (Truffer et al., 2008; Voß et al., 2006). However, in the context of missions, where governments play a leading role in defining socio-technical end states and thus indirectly determining socio-technical futures, Sustainability Foresight needs to be adapted to accommodate the dynamic interplay between top-down government influence and collective input in shaping socio-technical transitions. Moreover, it has a strong focus on the social expectations of stakeholders, covering only the earliest stages of a participatory foresight exercise being unable to inform policy on wider dynamics.

Scenarios are a commonly used tool as an entry point for exploring potential futures. For example, scenario planning (Amer et al., 2013), technology/vision assessment (Grin & Grunwald, 2000), horizon scanning (Amanatidou et al., 2012), value scenarios (Nathan et al., 2007), technology roadmaps (Kostoff & Schaller, 2001), and anticipatory governance in the broader sense (Barben et al., 2007) show how scenarios-based reflections can inform decision-makers on plausible futures (Rip & Te Kulve, 2008; Truffer et al., 2008). In the context of sustainability transitions, for instance, Eames and McDowall (2010) demonstrated how scenario-based workshops help identify which key enabling technologies are deemed most promising by stakeholders, and which may require additional support. The link between technological development and social and institutional aspects is central. By linking the long-term and strategic goals and missions to specific socio-technical pathways, scenarios provide input for deliberations with specific stakeholders on an operational and tactical level (Sondeijker et al., 2006).

4.3 Conceptualizing Mission-Oriented Transition Assessment

As indicated in the previous section, there is a need for an approach that facilitates the midstream processes of governing and implementing missions, which needs adaptations to existing approaches to the governance of socio-technical change. In this section, we conceptualize Mission-Oriented Transition Assessment (MOTA) as *a collective appraisal of current and future socio-technical changes to inform stakeholders, particularly policymakers, on how to govern missions*. Using the theoretical considerations from the theoretical background section (Section 4.2), this approach is conceptualized as follows (Figure 6). MOTA takes place in a confined space in which carefully selected stakeholders – or system representatives – use the predefined scenarios to deliberate on the dynamics and consequences of mission-oriented changes, and their structural positions and system configurations at large. We refer to such space that represents the various stakeholder groups as a *microcosm* (e.g., Fishkin, 2018).

In the context of MIPs, the expected transition dynamics tend to be explicated through top-down mission formulations in a predefined domain. Considering the required qualities of governance to be anticipatory, participatory, reflexive, and tentative, as well as the focus on transitions rather than single technologies, we use Constructive Technology Assessment as a point of departure and adopt several elements from Sustainability Foresight to account for structured ways of scenario development. Constructive Technology Assessment is an inclusive and reflexive approach that actively engages diverse stakeholders in collaborative discussions to assess emerging technologies, promoting normative orientation and iterative adaptation throughout the process (Rip, 2018). Sustainability Foresight is a participatory approach that explores, assesses, and strategically shapes socio-technical transformations, aiming to guide sustainable development efforts through collective, future-oriented learning and reflexive governance (Voß et al., 2006). Both provide starting points for the mission-oriented transition assessment and, as such, of the scenarios. However, the use of missions to provide directionality for socio-technical change requires several modifications.

MOTA consists of the following procedural steps. First, it involves mapping the mission and the mission-specific system to analyse its structure and ongoing dynamics. Different pathways toward mission achievement are then explored through expert scenarios to highlight system tensions and stakeholder behaviours. Next, these scenarios are assessed collaboratively in the *microcosm*, focusing on challenges and opportunities. This step fosters debate, identifies common ground, and addresses conflicts related to mission interpretations and stakeholder positions. Finally, the discussions are analysed to allow stakeholders to anticipate the next steps in the transition and to formulate policy recommendations guiding socio-technical change. The analysis considers both the outcomes and the discussions leading to them, providing insights into potential pathways for mission achievement and systemic dynamics and tensions within the mission-oriented system.

Given that scenarios have proven itself as a tool in these previous approaches, we adopt it as a tool for appraising mission-oriented transitions. MOTA incorporates scenarios as a tool to provide possible pathways as input for discussion, the scenarios are explorative in that they examine a range of possible futures and are strategic in that they help guide decision-making towards sustainable outcomes (Börjesona et al., 2006). These scenarios comprise plausible and potentially desirable narratives that articulate the wicked challenges for mission-oriented transitions: uncertainty, complexity, contestation, and, by extension, intractability. By putting the current condition of the transition in light of the mission, a back-casting approach is used to establish narratives of transition pathways (Rip & Te Kulve, 2008). In a workshop setting, system representatives are confronted with the scenarios to provoke reflection. In heterogeneous groups moderated discussions take place around these scenarios to anticipate the systemic consequences of the transition at various timescales considering the wide range of solution pathways. The desired outcomes of this procedural approach to MOTA are to bolster preparedness, social robustness, awareness, and alignment concerning mission-oriented transitions.

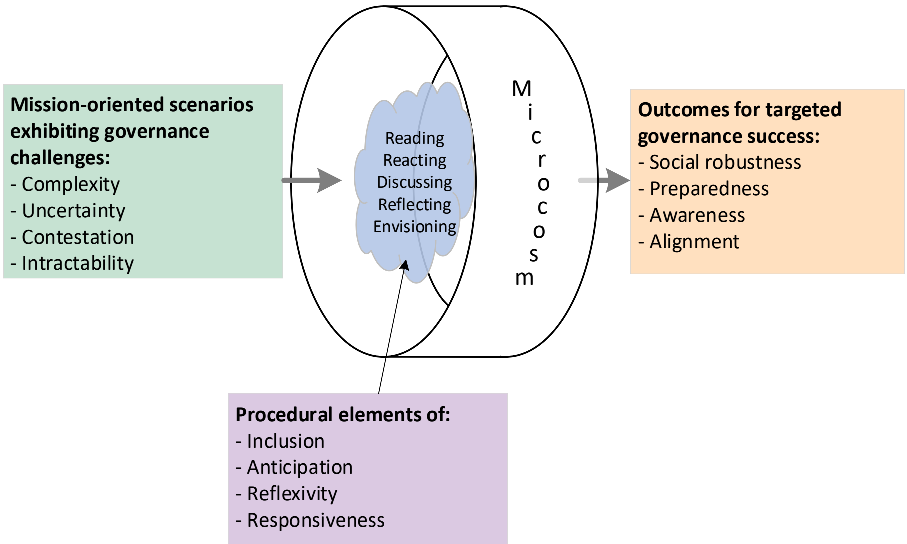

Figure 6. Conceptual outline of MOTA.

4.4 Methodology: Case application of MOTA

The theory-derived MOTA presented in Section 4.3 is only conceptually presented so far. The mission *Transition toward a CE in the Dutch infrastructure sector* has been selected as a case to evaluate and reflect on the conceptualized MOTA approach. Next, this case will be discussed, followed by an elaboration on the approach.

4.4.1 Case selection and introduction: Circular infrastructure by 2050

The conceptual MOTA approach was appraised using the circularity mission 'Circular infrastructure by 2050' in the Netherlands. Here, circularity was deliberately positioned as a mission with clear boundaries in scope and time, an extensive portfolio of related projects and strategies, a broad interpretation of the stakeholder field, and an inclusive governance approach (cf., Mazzucato, 2018a) through the 'Transition Team Circular Construction'. The Dutch infrastructure sector contains the transportation infrastructure and water works that serve mobility and water safety in the Netherlands. This mission was selected for several reasons. First, it is widely contested by various stakeholders who question its ability to address environmental concerns and believe it has become a goal in itself (Chapters 2 and 3). Second, although the Dutch circular construction sector is a leader in waste management and reuse, it is still in an early transition stage (Giorgi et al., 2022). Third, the Dutch government's top-down policy on circular construction has created institutional fragmentation and high stakes. The sector requires systemic change that goes beyond technological improvements to reconsider practices, institutions, organizational processes, and actor relations (Transitieteam Bouw, 2018). Although current innovations are mainly at the niche level (i.e., experimentation spaces that are protected from mainstream institutional pressures), there are several yet arduous efforts to scale them up and institutionalize conditions that lead to circular practices (Chapter 2). The slow transition dynamics in this complex, uncertain, and contested mission context provide a rich empirical setting to explore and anticipate the next steps toward a circular future for testing MOTA.

The Dutch infrastructure sector involves various public bodies coordinated by different ministries and regional governments. It comprises multiple subsectors, e.g., road infrastructure, waterways, and flood protection, with no clearly delineated boundaries, resulting in fragmentation by nature (Dave & Koskela, 2009). The stakeholders are highly interdependent due to the regional nature of the construction market and the modest size of the country. The sector involves over 1,100 contractors of which only thirty-four employ over a hundred people (EIB, 2021), while demand comes from only a few large public clients and several hundred smaller ones. It also includes suppliers, consultancy and engineering firms, knowledge institutions, financers, societal pressure groups, and lobby groups (Chapter 2). The stakeholders' involvement and impact in the (circular) transition process vary considerably. Road construction generates the most turnover, followed by concrete civil engineering structures.

The past decades were characterized by a neoliberal system where the market is dominant in determining the direction for solutions, shifting responsibilities toward market parties. Currently, public-private relations are slowly shifting toward a more collaborative approach (Kuitert, 2021). The sector is challenged by the huge task of renovating and replacing infrastructure assets across all tiers of government in the next few decades, with tight budgets and capacities (Bleijenberg, 2021). The infrastructure network is generally considered of high quality, resulting in high standards for circular alternatives. These context-specific conditions could affect a mission-oriented transition.

The Dutch government set the mission for the country to be fully circular by 2050, including a separate mission for the construction sector addressing both buildings and infrastructure (IenW & EZK, 2016). This 'Circular Infrastructure by 2050' mission was supported by a strategy report that outlines three objectives (Transitieteam Bouw, 2018): (1) the high-grade utilization of available resources and waste flows; (2) the substitution of fossil and non-sustainably produced resources by widely available and renewable alternatives; and (3) the rethinking of consumption in conjunction with the reconfiguration of products and production methods. The same strategy report acknowledged that a CE should be understood as a utopian vision to mobilize stakeholders in a shared direction. The Construction Transition Team issued a strategic agenda to transform the sector into a circular one by 2050 with intermediate mission goals for 2030 and set out annual Implementation Programs to monitor the mission's progress. Given the high levels of uncertainty, we decided to select the intermediate mission goals for 2030 as our focal point instead of those for 2050, to support participants in formulating strategic insights to do things differently and to be better equipped to deal with the transition – i.e., action perspective. These enable stakeholders to create managerial outlooks to shape the transition through bottom-up actions.

4.4.2 Case application steps

First, a Mission-oriented Innovation System (MIS) analysis was applied as a starting point for the scenarios (cf., Hekkert et al., 2020), using the recent studies of the Dutch infrastructure sector executed in Chapter 2 and by Bours et al. (2022). We used these studies to determine the system boundaries, mission formulation, key actors, ongoing transition developments, and major tensions and barriers. These elements were analysed to understand recent multi-level dynamics regarding circular solutions, system actors, interactions, and institutions (Geels, 2005). Next, we formulated a diverse set of plausible landscape events (i.e., exogenous events and long-term developments) to substantiate the scenarios with tensions that provoke stakeholders to take certain positionings regarding the circularity transition. While these external shocks were inherently contingent and partly sector-specific, they were carefully selected to relate to wider ongoing external developments and trends, such as political and societal discourses, geopolitical dynamics, and socio-economic developments.

We structured these system outlines and landscape events to design two fundamentally different socio-technical scenarios as narratives that depicted specific developments concerning the mission. These scenarios were used to explicate implicit expectations about the landscape, regime (i.e., the socio-technical system formed by incumbent actors, mainstream technologies, and prevailing institutions), and niche-level dynamics (Rip & Te Kulve, 2008; Schot & Rip, 1997). Following the approach of Rip and Te Kulve (2008), these scenarios included multiple technologies and various institutional, social, and organizational dimensions and were explicitly related to tensions between the existing and aspired systems. The narratives were open-ended with regard to leaving space for an infinite number of potential pathways, including different framings, interpretations, institutions, and solutions to attain the mission using a back-casting approach (Hofman et al., 2004). We designed the two following the dichotomy of whether either the government-led infrastructure clients or the private sector parties would take the lead in converging circular solutions.

Table 12. Main elements of external shocks and developments and two scenarios.

External events	*Scenario 1: Proactive government*	*Scenario 2: Innovative market*
Heavy storm Collapsing viaduct Extremely high material prices Stagnating climate policy Climate activists win a court case against large infrastructure project	Centralized planning and budgeting of infrastructure system Framework agreements for standardization of solutions Coordination between clients Lifecycle extension and reuse innovations Asset-orientation Standardization of circular solutions	Ownership of assets to market parties (as-a-service) Multi-year innovation public-private contracts Contractor networks Material innovations Project-orientation Large diversity of circular solutions

Prior to the MOTA workshop, the two preliminary scenarios were assessed in a small-scale workshop with five practitioners from Rijkswaterstaat to review the richness, desirability, plausibility, and possibility of the narratives. This small-scale workshop led to an improved set of events to make the scenarios more accessible for stakeholders. Moreover, both politics and governance gained a more prominent role in the revised scenarios as these were identified as key factors in the sectoral developments. We incorporated these changes in the two revised scenarios. Key elements of the external events and two scenarios are listed in Table 12.

Next, we selected stakeholders that represented the system as described in the two MIS analyses. With the help of practitioners from our networks, we made a list of 30 potential participants that covered the full MIS. Participants were eventually selected to represent a diversity of values and perform a variety of functions in the infrastructure system, and were either/or both influential, strongly influenced by, or knowledgeable on the sectoral circularity transition. From this list, we approached twenty-four individuals to allow for four group discussions of a maximum of six persons. Of these twenty-four individuals, seventeen eventually participated in the workshop. The list of participants is shown in Table 13.

Table 13. List of workshop participants.

Code	*Organization type*	*Role*
AM1	Municipality	Alderman
BM1	Government committee	Board member
CM1	Construction firm	Commercial manager
CN1	Standardization institution	Consultant
CN2	Consultancy firm	Consultant
CN3	Sustainability consultancy	Consultant
DA1	Province	Director asset management
DM1	Ministry	Director
DM2	Sustainability consultancy	Director
PM1	Ministry	Policymaker
PM2	Sector association	Policymaker
SB1	Financial institution	Sector banker
SE1	Knowledge institute	Sustainability expert
SM1	Large construction firm	Manager sustainability
TM1	Infrastructure agency	Transition manager

To both accommodate the strategic deliberation of participants and provide input for mission-oriented transition governance that embodies forms of reflexivity and anticipation, we took the following steps during the workshop.

First, the authors, acting as moderators, introduced the mission and scenarios. Next, participants were divided into four heterogeneous subgroups. To keep the narratives in the initial discussions separated, two groups received Scenario 1 and the other two groups Scenario 2. In the first discussion round, the groups spent an hour discussing the scenarios to critically reflect on their position toward the transition and to reveal possible system tensions. In the second discussion round, groups were recomposed into four new heterogeneous groups, each focusing on both scenarios to confront the many perspectives on the two possible futures discussed in the first round. The stakeholders collectively anticipated the transition, potential actions, changes in roles, and possible barriers and opportunities for both stakeholders and the sector as a whole.

All discussions were recorded and transcribed, resulting in detailed accounts of the discussions between the stakeholders containing eight 7,000-to-8,000-word transcripts. Using a focused coding approach (Saldaña, 2013), coding categories were established iteratively on two levels, containing forty-four sub-categories (i.e., importance of technology; asset ownership; transition phases) that were clustered into six main categories (e.g., stakeholders and roles; system change and upscaling; collaboration and networks; circular problems and solutions; transition approaches and programmes; and sectoral developments and dynamics). This approach allowed us to compose an overview of the various perspectives on the problems, solutions, and roles of each stakeholder. The coding of perspectives allowed us to identify a large diversity of issues related to contestation, complexity, and uncertainty to inform decision-makers.

Next, a survey was distributed among participants to reflect on the MOTA governance framework. Four questions were raised: (1) *how did the workshop align with your expectations?*; (2) *did the scenarios help in reflecting and anticipating the circularity transition?*; (3) *what key insights did the workshop yield?*; and (4) *what would be your main advice to policymakers?* Fifteen out of the seventeen participants completed the survey. The answers were used to reflect on the MOTA's perceived usefulness. Finally, both the coded quotations and survey results were linked to the four proposed governance modes (i.e., participatory, anticipatory, reflexive, and tentative governance). This enabled us to appraise how MOTA helps in mission governance considering the various relevant governance modes (Table 11). The quotes in the next sections are directly translated from Dutch into English by the authors.

4.1 Appraising MOTA in circular infrastructure

The analysis presented in this section is structured around the aspired outcomes of the four integrated governance modes, namely, social robustness, preparedness, awareness, and alignment (Section 4.2.3). For each of these, it is described how the empirical results relate the principles of MOTA to the case of circular infrastructure by 2050. Finally, we reflect on the application and the insights it provides for further the mission-oriented transition towards a circular infrastructure sector.

4.4.3 Social robustness

The creation of a *microcosm* proved to be useful in eliciting discussions that went beyond the narrow confines of individual stakeholder viewpoints. Regardless of differing viewpoints and animated debates, participants unanimously agreed that the inclusive workshop setting, characterized by its diverse participants, was instrumental in collectively charting the path toward mission attainment. Illustrated by a member of the government committee (BM1): “While most insights were not necessarily new, this approach reconfirms that it is a joint challenge to achieve the mission. It really stresses the importance of ambitious and predictably tightening mission goals”. This underscores the importance of involving a diverse array of stakeholders to collectively appraise steps forward in mission attainment.

The involvement of diverse stakeholders in mission governance was argued to be crucial in creating more robust outcomes because both the challenges and the interdependencies between the stakeholders are too complex to address by a single organization. Yet, a significant number of both public and private stakeholders argued that, despite the need for inclusion, the government should take the lead in the transition for several reasons. Firstly, the government established the mission and owns the infrastructure assets, giving them a substantial degree of power. Secondly, as asset owners, clients, and legislators, they are deemed to possess the most effective tools to steer the transition compared to other stakeholders, including the ability to create and adapt markets. Thirdly, while it is a collective effort, other parties have even less agency and fewer incentives to take the lead. All these reasons meant that stakeholders allocated the primary responsibility for achieving the mission to the central government.

Various participants emphasized that governance and organization issues deserve priority over technological ones. These views on non-technological solution pathways were divergent as well. It appeared that an integral and relation-based approach to infrastructure management stages and stakeholders, such as involving contractors in pre-project stages or demolition companies in the design stage, is essential to achieve a circular sector. This requires new approaches to collaboration, procurement, contracting, and organizing. Although initiatives such as framework agreements and series-based approaches were mentioned as fruitful directions, they seemingly have not yet resulted in structural changes. Nevertheless, many participants, including a policymaker (PM1), considered these key aspects for a future transition: “You need to become collectively part of a *bouwteam* [specific Dutch type of public-private construction team]. You won’t make it on your own, so this requires radically different ways of collaborating.” A closer alignment between governments was argued to offer a collective perspective and create a level playing field for circular markets, which should match the long-term visions discussed earlier. The discussions that are central in MOTA facilitate such processes that consider continuous collaboration in the transition effort.

The adoption of approaches with higher degrees of participation was encouraged by all participants, mainly because governments tend to lack the skills and knowledge to formulate market conditions that promote circularity while remaining technically and organizationally feasible. A civil servant (DM1) argued: “[Including market parties] is the only way that it possibly could work. If civil servants are going to determine the technical specifications of a circular asset, then we have a big problem.” While the central government may possess knowledge and capacity, its deficiency was argued to be more pressing for local governments. To deal with the natural subordination of market parties as contractors to public parties as clients, alignment between governments at all levels was mentioned to be essential for creating a collective action to develop and implement circular solutions. An alderman (AM1) stated: “Only if you make collective agreements [as a local government], you can take steps in mobilizing the market.” It was argued that achieving this would require governmental interventions that guide solution pathways. These discussions facilitated through MOTA led to broad acceptance of the need for inclusion for achieving broad support and optimal use of expertise to develop and select the best solutions for addressing the mission.

It was noted during the MOTA workshop that the expectations and envisioned role changes could shift the stakeholders’ power dynamics and mutual relations. As a result of these changing power dynamics, it was argued that novel interdependencies and power relations are likely to appear between stakeholders. One example may involve other types of marketplaces to match supply and demand, for example, in the context of reusing materials. Additionally, the relationship between portfolio planning and storage was said to require re-evaluation as the distinction between politicians and civil servants has been obscured over the past decade. This calls for the decoupling of long-term perspectives necessary for circularity from short-cyclical politics. Lastly, when involving market knowledge in infrastructure management, budgeting, and planning processes, new structures are necessary on the client side to enable collaborations beyond individual projects. However, as a market representative (PM2) argued: “[Market parties] really appreciate these involvements because they are valued on their knowledge. This creates an equal and trust-based position at the table.”

In conclusion, MOTA seemed able to offer an inclusive approach to governance that helped cope with the complexity ingrained in mission-oriented transitions, providing insights that could significantly improve the social robustness of mission attainment. It appeared to assist stakeholders in identifying diverse values and worldviews while duly clarifying the unique roles and responsibilities of government entities in the mission-oriented transition.

4.4.4 Preparedness

Participants generally regarded the scenarios as appropriate to structure discussions on future pathways because they allowed participants to take positions on which people could explicitly agree or disagree. By discovering each other’s underlying arguments, the scenarios helped gain insights into wider system dynamics. Furthermore, the scenarios were argued to channel discussions toward concrete and plausible transition pathways. While some groups actively discussed the mission in terms of directionality and feasibility, other groups took the mission for granted and merely discussed the pathways. The introduced pathways were highly contested, including the perceived and expected roles of various stakeholders. Although the moderators were equipped with guiding questions and a list of possible system tensions, discussions between participants proceeded without much moderation, presumably because the scenarios provided enough input for in-depth debates.

Not only did the scenarios contribute to increased anticipation, but also the workshop discussions were argued to strengthen the preparedness of the participants. For example, discussions revealed that the proposed changes would significantly impact stakeholders and their roles. For example, current dominant procurement approaches have a strong prescriptive character, which offers little room for contractors to distinguish themselves in terms of circularity. However, novel approaches were said to gain momentum, taking a more integrated perspective on asset lifecycle, asset portfolio, and stakeholder involvement. These procurement approaches prioritize collaboration skills, output quality, long-term benefits, and innovativeness, requiring market parties to adopt different practices to win tenders. Moreover, these approaches often include ambitious sustainability and circularity requirements where quality-oriented market parties were argued to potentially better compete with cost-efficiency-oriented ones. While some participants foresaw challenges and financial losses for laggards, participants from both the public and private sector organizations indicated to accept this transformation, as articulated by a network organization manager (PM2): “Actors that don’t want [to take part in the transition], will place themselves out of the market. I am convinced that, for example, when an SME doesn’t make steps [on circularity], it won’t exist anymore ten years from now.” A significant debate revolved around asset ownership in revised business models. Circular business models, such as producer-take-back systems and as-a-service contracts, were by many considered unhelpful due to the long lifespans of infrastructure assets. Participants argued that infrastructure is a public good and that ownership should therefore remain in the public sector. This would limit the applicability of novel business models promoted in the CE discourse.

We saw various ways in which the anticipation of socio-technical changes took shape in the discussions. An example of the anticipation of a changing socio-technical system was that market parties acknowledged a social responsibility for themselves in the transition. Participants explained that strategically investing in circular solutions would allow them to fulfil a certain duty toward society, while it could simultaneously provide them with a competitive advantage in the long term. In terms of technological solution pathways, the following directions were commonly discussed: a modular and adaptable design for reuse and lifespan extension, reducing emissions during construction and operation, reusing existing assets, components, and materials, and using low-impact and regenerative substitution materials. To illustrate the divergence of priorities, a consultant (DM2) stated: “We should focus on creating the conditions for future reuse by thinking about design principles that promote modularity and disassemblability […] since it is way easier to fix in long-term programming and less risky compared to reusing existing [infrastructure] that has never been designed, maintained, managed, or monitored to be reused.” However, consensus emerged that a combination of these solutions is necessary, depending on the type of infrastructure asset and contextual factors. A public manager nevertheless warned that some solutions that have an immediate effect on circularity, such as high-quality recycling, merely increase efficiency in the current system rather than promoting an inherently circular system. This could reinforce lock-ins and impede the attainment of long-term circularity goals. These insights were plenary shared and enabled the participants to strategically position themselves more effectively concerning the CE mission.

In conclusion, MOTA’s anticipatory character proves useful for addressing the uncertainty inherent in mission-oriented transitions. Scenarios serve as useful tools in preparing participants for a multitude of potential solutions, facilitating discussions that bring explicitness to agreement and disagreement. As the discussions venture into technological solutions, they underscore the complexity of the transition and the need for adaptability and flexibility in the face of evolving socio-technical systems.

4.4.5 Awareness

Survey results shed light on the efficacy of MOTA, with an overall appreciation for its ability to stimulate reflection among participants regarding their roles in the transition. Out of the fifteen respondents, six acknowledged that MOTA had strengthened their awareness regarding the collaborative nature of the transition. Additionally, some participants noted they gained an appreciation for reused and bio-based alternatives, recognizing their significance in the transition. This was the result of both the discussions with others and the scenarios. These insights into diverse solution directions are widely regarded as critical prerequisites for stimulating system-level change. The survey moreover revealed the absence of a shared direction concerning circular infrastructure, an overemphasis on technology, and an incomplete overview of promising circular developments within the sector. Notably, results confirmed our aim that MOTA supports interaction, knowledge exchange, and network building, as participants actively sought the contact details of their peers to facilitate future communication.

Throughout the MOTA discussions, divergent ideas emerged concerning preferred solutions, governance approaches, and organizational implications. Consequently, transparency in the various solution pathways increased, which is conditional for a clearer and more coherent vision for the future of circular infrastructure. To explore such a vision, participants expressed the need for a multi-decade back-casting approach to determine ways forward. This implicit call for reflexivity increased awareness of the diversity of, sometimes conflicting, stakeholder ideas and positions, which was argued to increase the stakeholders' ability to strategically position themselves in the transition towards a circular future.

Furthermore, the discussions during the MOTA workshop delved into various perspectives on addressing transition barriers, revealing multifaceted approaches. Notably, the deteriorating condition of existing infrastructure emerged as a pivotal factor in the transition. On the one hand, it presented opportunities for circular solutions, such as extending the lifespan of infrastructure and promoting reuse. On the other hand, it posed challenges in prioritizing circularity within current infrastructure management paradigms. A provincial manager (DA1) pointed out: "No matter how much money we allocate to circularity, with the current approaches to managing infrastructure, we just won’t make it.” This sentiment was echoed by a contractor (CM1), who emphasized the need for transformative change: “Fully circular in 2050? How on earth could we manage this if we stick to the ways we did it in the past and are still doing it?”. Given the multitude of challenges within the sector, with circularity being just one facet, it became evident that changes beyond circularity were imperative to realize the desired circularity goals.

Within MOTA, participants’ perspectives varied regarding the scale of changes required for systemic transformation. While some advocated for incremental steps to maintain feasibility, others championed the need for radical and holistic changes. An example of such a radical change involved the potential shift of asset ownership from government clients to market parties, incentivizing lifespan extension and reuse. This transformative step would necessitate a comprehensive restructuring of financing mechanisms, asset management practices, and risk management strategies. Conversely, some participants expressed scepticism about the likelihood and feasibility of such radical changes, irrespective of the stakeholder taking the lead.

In conclusion, the group discussions and scenario input within the MOTA workshop provided novel insights for both participants and decision-makers into the diverse perspectives on how to best achieve the mission. These deliberations from the discussions are thought to not only empower participants to position themselves strategically within the transition but also make policymakers aware of what solution pathways should either or not be promoted and selected. An important note is that the participants did not necessarily agree more with one another but gained a better understanding of each other’s perspectives.

4.4.6 Alignment

MOTA incorporates forms of tentative governance to foster alignment as new insights emerge, hence supporting the responsiveness of participants to the transition through exploring the various ways of positioning themselves. This responsiveness is not limited to stakeholder interactions but extends to encompass solution configurations and policy adaptations.

While most indicated that the discussions on the diverse perspectives were useful, some participants expressed frustration when learning about the misalignment between the participants’ outlook on the transition. This frustration was voiced by a consultant (DM2), who observed: “This is – again – a platform in which we all keep dreaming and talking, while there are so many ways in which we just can start doing things. We only need to define the concept by making its parts measurable.” Nevertheless, it is noteworthy that despite this, participants widely recognized the significance of engaging in diverse discussions to better align their perspectives with each other, with policies, and concerning solution directions.

In considering the next steps towards transitioning to circular infrastructure, participants frequently encountered practical barriers, stemming from the structural characteristics and dynamics of the sector. A significant issue was the extended lead times associated with infrastructure projects, resulting in decisions taking years, if not decades, to come to fruition. The benefits of circularity could take even longer to materialize, spanning multiple decades. As argued by a consultant (CN3): “Circular choices should be made much earlier in the process. Because of the long lead times, you are just playing catch-up all the time.” The sector’s conservative and risk-averse culture emerged as a pervasive barrier, with one of the primary consequences being its limited appeal to creative, ambitious, and socially engaged talent, further exacerbated by the sector’s labour shortage. Moreover, the sector’s narrow profit margins, high risks, and high stakes explained the market parties’ protective stance, prioritizing their short-term financial interests over circular solutions. Both public and private entities acknowledged the scarcity of competitive markets for circular solutions. While discussing such barriers in a MOTA setting could appear demotivating and paralyzing, it seemed to help in aligning the various perspectives on ways forward while avoiding or removing such barriers.

Several potential consequences associated with solution pathways came to the fore in the discussion, which illustrates how greater alignment can be achieved. First, instilling a cultural shift within the sector necessitates a significant sense of urgency, a factor deemed unlikely to emerge organically. Various approaches were suggested, including inspirational lectures, the integration of circularity into employment contracts across organizations, and the utilization of stakeholder deliberations. Second, the call for broader and earlier stakeholder involvement was recognized as demanding a more tentative approach, as prevailing procurement methods and organizational processes typically do not prioritize such inclusion. Lastly, participants noted that existing pilots and experiments often seem to be introduced on an ad hoc basis. Still, they could be significantly more effective if strategically linked to long-term visions aligned with circularity goals, thereby promoting learning and scaling. These insights offer tangible examples of how MOTA plays a role in mobilizing actors to actively participate and position themselves in the transition.

Various examples emerged during the discussions within MOTA to further amplify the responsiveness of stakeholder groups. For instance, the heightened focus on multiple lifecycles was expected to elevate the role of demolition contractors during the design and construction phases. The earlier discussed revised procurement approaches were also posited to strengthen the involvement of such stakeholders. Additionally, knowledge-driven entities, including universities and research institutes, could assume a more proactive role in co-developing solutions such as novel technologies and monitoring practices, thus expanding learning opportunities beyond individual projects. Research was stressed to be a potentially critical enabler for justifying circular pathways and lending legitimacy to the selection of circular solutions especially on the client side. Suppliers, a vital stakeholder group in the transition, were also anticipated to undergo substantial changes, particularly concerning their influence on the inflow of virgin materials and their potential to facilitate resource loop closures. However, their involvement in introducing substitute materials was predicted to be challenging, given their vested interests in incumbent supply chains, including profit motives. Notably, the utilization of scenarios within the *microcosm* setting appeared to be effective in sparking discussions that enhance the anticipation of forthcoming socio-technical changes, particularly considering stakeholder positioning.

The identification and sharing of these barriers proved instrumental in defining concrete actions for the participants. Moreover, the scenarios were argued to effectively show the consequences of not responding adequately to particular challenges, which motivated individuals to actively call for action. Furthermore, these insights hold the potential to inform policy-making efforts geared toward navigating the evolving landscape of the transition effectively.

4.4.7 Reflection on the case results

The insights above indicate that MOTA serves as a dynamic platform for stakeholders to collectively address misalignment, fragmentation, and practical barriers. By actively engaging in discussions, sharing insights, and identifying barriers, participants seem better positioned to align their perspectives and collaborate toward sustainable solutions. Several insights that potentially resonate in wider transition dynamics are discussed below.

The public nature of infrastructure has significant implications, particularly its dependence on short-term political cycles for budgets and objectives. This dependence is exacerbated by administrative fragmentation both vertically and horizontally, making it challenging to introduce long-term perspectives for realizing circular markets. Such a lack of a long-term perspective becomes particularly problematic for societal challenges and missions dealing with contested solution spaces, which is the case for circular infrastructure (Wiarda et al., 2023). Not only does contestation hamper the mission’s effectiveness but it also sparks competition among public bodies for limited market capacity, with market parties favouring the least ambitious client.

The public and asset-based nature of the infrastructure sector puts public clients in a dual role. On the one hand, they need to define requirements for infrastructure projects, while, on the other hand, they are tasked with owning the infrastructure assets. Our findings revealed that clients actively engage in both the innovation enactment cycle, by shaping the conditions for innovation, and the selection cycle, for example by acting as procurers of circular solutions or by acting as regulators (Lenderink et al., 2022). This blurs the boundary between those who initiate and those who select innovations, differentiating the enactment cycle of stakeholders within the innovation process from the selection cycle of external entities (Garud & Ahlstrom, 1997). Although the most intricate knowledge about infrastructure and novel circular technologies resides in the market, clients were urged to act as change leaders because of their dual roles. Nevertheless, they were encouraged to involve market parties in defining solution pathways.

The results highlight a dilemma between incremental solutions that immediately increase circularity in projects (e.g., improving recycling efficiency) and radical solutions that are more challenging due to their systemic nature (e.g., closed supply-demand mechanisms for element reuse). While the former arguably risks creating a lock-in that prevents fundamental forms of circularity, the latter risks being too complex even though it holds long-term potential for achieving circularity goals. Discussions in the MOTA workshop often adopted a short to medium-term view on solutions of the former sort, but, at the same time, participants acknowledged that achieving systemic change in line with the mission necessitates a long-term perspective. This reconciliation becomes particularly challenging when mission goals are ambiguous – as is the case with circularity – complicating methods like back-casting. Tensions between optimization and systemic change are extensively discussed in the literature (e.g., Geels & Schot, 2007; Rogge et al., 2020). Governance frameworks such as *radical incrementalism* (Swilling, 2020) and the *small wins framework* (Termeer & Dewulf, 2019) advocate incremental steps while pursuing long-term transformative change to address this tension. Such frameworks could prove valuable in empirical contexts of governing missions.

Finally, the discussions of participants emphasize that the transition faces limited technological challenges. While discussions in both practice and literature often revolve around technological solutions and neglect social and institutional aspects, it is evident from our results that organizational and institutional barriers represent the major impediments to the transition. This aligns with the view of Truffer et al. (2017), who advocate to cease solely fixing on technology in TA. Nevertheless, a substantial portion of experimentation and scientific research continues to concentrate on the technological facets of circular infrastructure, indicating a disconnect between recommendations and actions.

4.5 Discussion

In this chapter, we explored MOTA as a governance approach to deal with the complexity, uncertainty, contestation, and subsequent intractability of wicked problems and the associated mission-oriented transition. Our case demonstrated how such an approach brings together stakeholders to reflexively anticipate possible, probable, and desirable outcomes and mission pathways, not by assessing predictions but by articulating and sharing expectations. Doing so strengthens the social robustness, preparedness, awareness, and alignment of mission governance. As such, MOTA addresses the urgent but unresolved question of “what is considered a desirable future, and (even if we assume consensus) how do we get there?” (Patterson et al., 2017, p. 8) by articulating stakeholders’ worldviews and values. As such, it aims to improve governance responses surrounding mission-oriented innovation. The study’s anticipatory deliberations reflexively revealed conflicting stakeholder values and worldviews.

In this approach, first-order insights were gained regarding the structural transition barriers, possible ways forward, and the respective implications for stakeholders, roles, and forms of collaboration. As discussed in the previous section, these insights informed the participating policymakers on how to accelerate and shape missions. Particularly, the use of scenarios in the workshop setting was regarded useful to prepare participants for the diverse range of potential solution configurations to address the mission and to align these differing mission-oriented pathways. Second-order reflexivity emerged regarding the meaning, desirability, and feasibility of a CE in the infrastructure context. While scholars argue that missions should be bold (Mazzucato, 2018b), stakeholders openly questioned the feasibility of the mission in the first place, which may undermine its legitimacy (Elzinga et al., 2023). This leaves the dilemma between whether and how the mission formulation and strategy should be adjusted or whether policymakers should value continuity. Nevertheless, results confirmed the value of using missions for providing direction – or acting as boundary objects (Janssen et al., 2023).

While it is argued that missions should be precisely formulated (Mazzucato, 2018b), clear definitions are often not possible given the complexity, uncertainty, and contestation associated with wicked problems. Many participants held different understandings of circularity and hence advocated clearer visions and definitions before changing and monitoring practices. Simultaneously, policymakers argued that they did not possess sufficient knowledge, prompting standstills or waiting games (Parandian et al., 2012). As a result, mission governance was met with tensions between dimensions of directionality and feasibility and between clarity and open-endedness. A tentative governance perspective could resolve this issue by stipulating that there is no straightforward answer and that decisions need to be made while acknowledging an insufficiency of knowledge (Kuhlmann et al., 2019; Stilgoe et al., 2013).

Change-oriented leadership, coupled with broader stakeholder involvement, could help overcome the 'waiting games' between market players seeking clarity on solution pathways and clients awaiting proven circular solutions (Parandian et al., 2012). However, distributed governance complicates such a guiding role, leading to policy coordination failures (Weber & Rohracher, 2012). One approach to address this failure is the subsidiarity principle, which calls for aligning national and supranational goals with local contexts in ways that meet local conditions (Wanzenböck & Frenken, 2020). Nevertheless, results also call for inter-governmental alignment on preferred solution pathways to reduce market uncertainty and encourage investments in promising solutions that could transcend individual projects or contexts. Since alignment is not always possible, MOTA may help foster alignment through forms of reflexivity and inclusion of stakeholders in line with the principles of *agonistic governance*, which promotes making decisions regardless of and acknowledging fundamental and often irreconcilable disagreements (Scott, 2021).

Reflexive, anticipatory, participatory, and tentative governance require continuous efforts to be effective. The large uncertainty and non-linearity result in the continuous emergence of novel determinants on the progression of the transition. Similarly to Sustainability Foresight and Real-Time Technology Assessment (Guston & Sarewitz, 2002; Voß et al., 2006), MOTA could benefit from being performed periodically throughout mission lifecycles – e.g., mission formulations, implementations, and evaluations – to support governance along the way and serve as a monitoring exercise. Here, previous insights could inform new assessment exercises to support incremental mission governance and to refine scenarios with novel developments, experiences, and insights – and as such further promote reflexivity.

MOTA was primarily developed to deal with wickedness in mission governance to subsequently prevent transformative failures (Schot & Steinmueller, 2018b), yet the results suggest that the creation of a *microcosm* also creates a platform that addresses structural system failures (Weber & Rohracher, 2012). For instance, MOTA could potentially play an important intermediary function by connecting heterogeneous stakeholders, stimulating possible interaction, and addressing network failures. It furthermore led to a melting pot of new ideas and perspectives, creating spaces similar to 'small worlds' (Watts & Strogatz, 1998), 'trading zones' (Galison, 1997), 'local buzz' (Bathelt et al., 2004), and 'hybrid forums' (Callon et al., 2009) in which stakeholders can obtain and exchange both explicit and tacit knowledge for decision-making. Moreover, such space could also act as ‘mission arenas’ to collectively govern missions (Elzinga et al., 2023; Wesseling & Meijerhof, 2023).

For a broader use of MOTA, it is important to highlight that scenarios should be linked to the transition phase to which MOTA is applied. In our case, the transition of our case study was one of an early stage (Chapter 2; Bours et al., 2022), while a more institutionalized transition would be associated with a more convergent solution space (Wanzenböck et al., 2020). This would likely require and invoke other types of scenario-based discussions. In our case, scenarios were developed by the researchers using previous case-related studies. However, scenarios could also be developed inclusively, potentially resulting in other focal points and possible transition pathways that are deemed more acceptable, legitimate, and desirable (cf., Voß et al., 2006). Ultimately, combining forms of inclusion, anticipation, reflexivity, and presumably responsiveness could enable forms of ‘collective stewardship’, potentially leading to more desirable outcomes (Stilgoe et al., 2013). Besides scenarios, other ways would be worth exploring to substantiate the discussions in terms of complexity, uncertainty, contestation, and intractability, such as serious games, artworks, and role plays.

Lastly, MOTA was employed to assess a specific mission and encouraged participants to consider the systemic consequences of a circular sector. Indeed, the discussions, fed by the predeveloped scenarios, anticipated a circular system specifically. However, the reality is complex, with multiple missions and wider developments occurring simultaneously, interconnected with the sector. Focusing solely on one mission may lead to blind spots for other sectoral developments. Therefore, it is essential to acknowledge uncertainties and unknowns (Stirling, 2010), and to present MOTA results alongside other findings when informing policy to offer a range of pathways and potential interactions that help avoid pitfalls of narrow single-mission perspectives.

4.6 Conclusions and future research

In this chapter we develop, present, and demonstrate MOTA as an approach to support the governance of mission-oriented transition by drawing from various streams of literature including wicked problems, TA, Responsible Innovation, and MIPs. This has resulted in an integral governance framework to facilitate forms of anticipation, inclusion, reflexivity, and responsiveness, which are necessary for dealing with the wickedness associated with mission-oriented transitions. To appraise transition pathways, we employed explorative scenarios as input for collective deliberations involving a diverse set of stakeholders (i.e., *microcosm*) and applied it to the Dutch case of ‘Circular infrastructure by 2050’. Both the participants’ reflections and the discussions’ analyses suggest that

MOTA contributes to the preparedness and awareness of stakeholders while yielding more socially robust and socially aligned mission outcomes. In this chapter, we not only developed the conceptual framework of MOTA but also demonstrated its application in practice.

The MOTA approach yielded various insights for decision-makers and stakeholders of the transition toward a circular infrastructure sector. The approach was generally regarded as helpful by the case participants and several insights resulted from the discussion that offer input for policies. However, insights underline the potential for further conceptualizing, testing, and advancing the MOTA approach as a tool for mission governance. More broadly considered, MOTA offers a practical approach that addresses important challenges associated with the governance of missions, such as lack of coordination between policymakers and multiple stakeholders or the disconnect between bottom-up experimentation and top-down directionality. Moreover, in larger mission-oriented initiatives, such as the EU missions, coordinating various stakeholders and aligning their efforts can be complex endeavours. In this regard, MOTA offers an easy-to-adopt approach for the establishment of an initial governance structure while creating a shared platform for stakeholder interaction.

MOTA was developed deductively and applied to a single case. This inevitably comes with limitations that need to be addressed by future research. For example, future studies should study whether and how insights yielded with the MOTA approach feed into practice. Furthermore, beyond the results retrieved from the workshop, research can explore the adoption of MOTA results by policymakers to reveal, for instance, whether and how MOTA contributes not only to the alignment of participant perspectives, but also to the alignment of the mission, mission formulation, and related strategies. This requires analysis in the domain of mission governance and related policy-making bodies. Moreover, a real-time form of MOTA (cf., Guston & Sarewitz, 2002) could reveal how it can be used as a long-term monitoring approach. Research should further investigate the applicability of MOTA on other scales of mission-oriented governance. Further inquiry could help understand the interactions between national and supranational missions, such as the governance of EU missions by national governments. However, applications in higher levels of government (e.g., supranational) will likely face additional challenges in terms of stakeholder participation because it is likely to generate increasing complexity in the stakeholder field.

To conclude, we present MOTA as a mission governance approach, emphasizing stakeholder participation for a collective appraisal of missions and transitions to tentatively adapt these in response to stakeholder feedback and changing circumstances. As such, MOTA may represent a needed approach for shaping mission-oriented transitions that are needed to address the societal challenges of our time.

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chapter 5

navigating institutional plurality in pursuit of a circular economy: the case of a public infrastructure organization

Abstract: The circular economy (CE) necessitates systemic changes that drive organizational transformations, presenting distinct challenges within public sectors, such as infrastructure. Due to their inherently hybrid nature, public infrastructure organizations must navigate substantial tensions between their existing and envisioned organizational structures and dynamics while undergoing such transformations. The aim of the study is to examine the organizational dynamics resulting from implementation strategies aimed at circular infrastructure in a public organization, considering the various institutional contexts in which it operates. By taking an institutional logics lens, the study shows how institutional complexity affects the implementation of circularity in the organization. Tensions arise due to the limited integration of the societal challenge logic associated with circularity principles into existing processes in the organization. The findings emphasize the imperative of organizational transformation to achieve systemic levels of circularity and a more sustainable future for the built environment.

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5.1 Introduction

The construction sector accounts for roughly two-fifths of the global input mass of materials (Circle Economy, 2023) and a similar share of greenhouse gas emissions (United Nations, 2022). A significant part of this industry relates to public infrastructure (e.g., bridges, viaducts, rail roads, waterways), which covers a substantial portion of the global material flows and stocks and is expected to double in the next 50 years (OECD, 2019). Given the significant attribution of global greenhouse gas emissions to material production (Hertwich, 2021), the transition towards the circular economy (CE) in infrastructure is crucial not only to reduce resource depletion and waste production but also to address climate change (Gallego-Schmid et al., 2020). The top-down imposed goals and missions relating to circularity create new institutional demands (Gümüsay et al., 2020), which put additional pressures on the available organizational resources, leading to additional complexity (Miron-Spektor et al., 2018). Fuelled by this increasing complexity, the degree of national and international implementation of circularity policies in the infrastructure sector lags behind targets (Giorgi et al., 2022; PBL, 2023).

Due to their pluralistic role not only as purchasers and asset owners but also as legislators and policy implementers, public infrastructure organizations have a pivotal role in the transition towards a circular sector. The dynamics of systemic organizational changes depend on the specific contexts (Ilyas & Osiyevskyy, 2022), which lie for circular infrastructure predominantly in the public nature, the long lifespans of infrastructure assets, the fragmentation of infrastructure ownership, and the industry's project-based nature (Chapter 2). Therefore, typical CE transition strategies, such as business model innovation (Bidmon & Knab, 2018; Bocken & Geradts, 2020; Lüdeke-Freund et al., 2019), are insufficient to shape the public sector's circularity transition (Hossain et al., 2020). A successful transition, therefore, requires fundamental organizational transformation (Ocasio & Radoynovska, 2016).

Understanding the interaction between systemic organizational dynamics and the implementation of circular policies aimed at achieving circular infrastructure is crucial to avoid encumbrance, or even paralysis, in the transition (Pache & Santos, 2021). Only then can the tensions arising during the endeavour to become circular be addressed (Greenwood et al., 2015), and strategies proposed and refined to ensure a successful transition towards a circular sector. Although it is widely acknowledged that public sector organizations use various approaches to organizational transformations compared to private sector organizations (Rainey, 2014), organizational transformation, in line with new external institutional demands such as the CE, has scantly been studied in the context of public sector organizations.

Extant studies (e.g., Droege et al., 2021; Klein et al., 2021; Klein et al., 2022) primarily focus on products and processes used within the organization (e.g., ICT system, furniture, office space). However, the major share of public infrastructure organisations' environmental and resource impacts stem from the assets managed by these organizations rather than from their organizational operations (UNOPS, 2021). They must maintain their ongoing business operations while transforming the organization to produce inherently circular outcomes (Sarja et al., 2021). This situation inevitably creates tensions between current and new practices (Farid & Waldorff, 2022). However, it remains unclear *how infrastructure organizations pursue the systemic circularity transformation while maintaining their business operations*.

To address this gap, this chapter contributes to the literature focusing on circular transitions in organizations with insights from a public infrastructure organization that aims to achieve circular infrastructure. Different and often opposing institutional demands, which render public infrastructure organizations intrinsically hybrid (De Waele et al., 2015), have been identified in organizational studies as critical determinants of the dynamics that affect organizational transformation (Greenwood et al., 2015). Additional institutional demands resulting from the circularity implementation make adopting an institutional logics lens suitable to study the respective organizational transformation dynamics (Ocasio & Radoynovska, 2016). These logics are socially constructed and historically grounded frameworks for adherence to an institution's regulatory, normative, and cultural-cognitive accounts (Friedland & Alford, 1991; Scott, 2014). This approach allows for examining how the adoption of various logics not only creates tensions between them but also serves as a potential mechanism for navigating external institutional pressures (Greenwood et al., 2011; Mair et al., 2015). In this way, the study responds to the call by Lounsbury et al. (2021) by explicating how an organization deliberately governs various logics to achieve organizational transformation. To reveal the tensions stemming from logic interactions and the resulting organizational responses, we investigated the national public infrastructure organization in the Netherlands, which has since 2016 been actively working towards acting circularly by 2030 and having fully circular outcomes by 2050.

The remainder of the chapter is structured as follows. First, the theoretical background is developed in Section 5.2 to establish a view of a public organization as a hybrid organization and to contextualize this within the institutional logics that underpin the CE from a public infrastructure perspective. Next, in Section 5.3, the research methods and approach are presented. This is followed by a case analysis of the logics related to the infrastructure management process and the circularity implementation process in Section 5.4.

The results are discussed in Section 5.5, the conclusions provided in Section 5.6, and, finally, suggestions for future research are presented in Section 5.7.

5.2 Theoretical background and context

5.2.1 Institutional plurality and logic multiplicity

Prior literature suggests that most contemporary organizations operate in pluralistic institutional environments, where multiple institutional logics are at play (Kraatz & Block, 2008; Mair et al., 2015). When operating in such environments, organizations must adhere to several institutional logics simultaneously to gain legitimacy from multiple relevant audiences (Perkmann et al., 2019; Suddaby et al., 2017). In addition to being socially constructed and historically grounded (Scott, 2014), they prescribe taken-for-granted assumptions, beliefs, material practices, rules, and values that are considered legitimate within an institutional environment to conform to (Thornton & Ocasio, 1999). In doing so, institutional logics play a crucial role in organizations as they link institutionalized structures and norms within societal sectors with appropriate organizational actions, decisions, and behaviour (Battilana et al., 2017).

Organizations that operate in pluralistic institutional environments require the capability to combine and exploit multiple, possibly contradictory, institutional logics to achieve their goals (Durand & Thornton, 2018). This implies that these organizations successfully integrate material and immaterial aspects derived from multiple institutional logics into their practices. When this pluralism creates tensions within an organization because of incompatible prescriptions from institutional logics, the organization experiences institutional complexity (Greenwood et al., 2010). To mitigate the negative impacts of these complexities on their activities, organizations must deal with divergent cultural expectations, values, understandings, and identities (Greenwood et al., 2011; Raynard, 2016). This means that when studying the organizational transformation of a public organization towards circularity, the full variety of dynamics between these logics needs to be captured. However, this comes with specific challenges, particularly in the context of public infrastructure.

5.2.2 Organizational hybridity in public infrastructure organizations

Due to their embeddedness in multiple and likely competing institutional environments and high institutional power, public organizations can be considered distinctly hybrid (Arellano-Gault et al., 2013; De Waele et al., 2015). Hybridity leads organizations to respond in diverse ways to external institutional pressures and demands. As Greenwood et al. (2011, p. 342) remarked, "institutional pressures […] are interpreted, given meaning and 'represented' by occupants of structural positions." Therefore, the interaction between multiple pressures has different consequences for the organization in different situations. Indeed, various logics within an organizational setting can be deliberately utilized to handle external institutional pressures (Farid & Waldorff, 2022).

The notion of hybridity necessitates specific responses to institutional demands, for which some organizations or departments and individuals within organizations are better equipped than others. This partly depends on their structural position and ability to draw from specific or various logics (Mair et al., 2015). However, this multiplicity of institutional responses within a hybrid organization might also lead to conflicts, resulting in organizational paralysis or even breakup (Pache & Santos, 2021). As a result of the institutional complexity, organizational hybridity increases the challenges involved in organizational transformation. Nevertheless, it might also employ this hybridity to respond appropriately to new institutional pressures, such as the ones introduced by the goal of becoming circular. Consequently, organizations may adopt hybrid characteristics to cope with pluralistic institutional conditions on the one hand while gaining legitimacy from relevant audiences on the other (Perkmann et al., 2019; Suddaby et al., 2017).

Although hybridity is not a new phenomenon in public organizations (cf. Denis et al., 2015), few studies have examined how organizational transformation leading from externally imposed pressures, such as circularity, interact in this public context. Given their close ties to the political arena and dependence on political decision-making (Verhoest et al., 2007), a public organization's ability to change and innovate differs considerably from a private one (Eneqvist, 2023). While their governance structures and level of autonomy may vary, public organizations are generally exposed to top-down political goals and missions in the sphere of delegated governance (Meyer et al., 2015). Amplified by external pressures related to an increasingly complex world (Smith & Tracey, 2016), public organizations face an ever-increasing institutional complexity, which increases hybridity (Battilana & Dorado, 2010; Jay, 2013). This demands the reconsideration of roles, tasks, and even purposes of public organizations (Braams et al., 2021).

Public infrastructure organizations are a unique type of public organization with distinct traits linked to their activities, governance, and interactions with their environment (Chapter 4, Termeer & van den Brink, 2013). First, the infrastructure owned and managed by these organizations generally has a lifespan of several decades, necessitating long-term planning and budgeting. Second, these infrastructure organizations act as both asset managers and facilitators of public-private projects, requiring a balance between asset management activities and new construction projects (El-Gohary & El-Diraby, 2010). Third, public infrastructure serves as both a facilitator of public activities and an influencer of the public space. This close relationship with the living environment ensures legitimacy and involves managing diverse interests. Fourth, the highly politicized environment in which public infrastructure organizations operate, characterized by short-term political cycles, poses challenges for long-term planning (Crain & Oakley, 1995). Lastly, these organizations rely heavily on market parties, suppliers, and consultancies for their operational activities and the eventual construction of infrastructure works. Consequently, these characteristics require the adoption of multiple institutional logics to navigate the diverse tasks and environments involved, which affect how conventional infrastructure processes are organized.

In public infrastructure, demands are primarily articulated by politics through central government bodies such as ministries or local governmental bodies like municipalities (Matinheikki et al., 2019). Public infrastructure organizations operating within the institutional contexts of both the political arena and the construction sector navigate at least two distinct institutional environments. On the one hand, they deal with the political environment that governs the organization (Brandsen & Karré, 2011), and, on the other, they must embrace a project-orientation approach based on professional norms that shape interactions with private contractors and other market parties (Frederiksen et al., 2021; Matinheikki et al., 2019). As both institutional environments must be addressed, one logic cannot be prioritized over the other, resulting in public infrastructure organizations being dissenting hybrids (Mair et al., 2015). For this reason, these organizations employ internal strategies to navigate these pluralistic institutional contexts (Kraatz & Block, 2008). Societal challenges, such as the CE, exert pressure on these strategies as they introduce new institutional pressures requiring organizational practice changes (Gümüsay et al., 2020). However, so far, it is not clear from the literature how public organizations, as distinct hybrid organizations, deal with an external challenge that urge them to transform and draw from distinctively different logics.

5.2.3 Transitioning towards circular public infrastructure

The transition towards the CE is one of the societal demands that require fundamental organizational transformation and puts additional institutional pressures on the organization (DiVito et al., 2022). Efforts towards a more environmentally sustainable future often clash with the dominant neo-liberal market logic that aims for economic returns and growth (Kemper et al., 2019). The coupling of the reduction of environmental impact with value retention and value creation has, from the start, been one of the main traits of circularity. For example, as one of the primary originators, the Ellen MacArthur Foundation (2013) spent a great deal of effort to achieve particular environmental sustainability goals through reinvention of business models and the concept of value to make sustainable behaviour economically profitable. However, recent research has shown how misalignment between existing logics hampers the introduction of novel business models aiming to incorporate sustainability into prevailing norms and expectations through interactions between different existing and new logics (e.g., Olesson et al., 2023; Vernay et al., 2022).

Although some advocate against it due to concerns about potential greenwashing (e.g., Bauwens et al., 2023; Corvellec et al., 2022), focus on economic viability is one of the main reasons for the increased traction of circularity in business and policy environments. In this context, Aarikka-Stenroos et al. (2021, p. 262) observed: "The CE seems to (re)shape the logic of value creation, not only for individual firms but also for value chains and networks, as the firm needs to acknowledge more and diverse actors and stakeholders for which the firm creates value." DiVito et al. (2022) go even as far as to speak of a *circularity logic* as opposed to a *linear logic*. Nevertheless, the high degree of contestation of circularity in the infrastructure sector (Chapter 2), as well as the lack of institutionalized circular practices (Buser et al., 2021; Greer et al., 2021), indicates that circularity, due to its lack of institutionalization, is not a field-level logic in the context of construction. Instead, it is informed by several existing field-level logics – primarily the *sustainability logic* and the *market logic*.

For an inherently hybrid public infrastructure organization to undergo a fundamental transition towards the CE, it needs to use, align, or adapt its internal configuration of logics to deal with the potential complexity introduced by implementing circularity. By introducing the goal to become circular, the organization brings in a new, conflicting logic that creates tensions between conventional infrastructure management processes and circularity implementation processes and can count on various potentially resistant responses (Malhotra et al., 2021).

5.3 Research methods

5.3.1 Case selection and description

We chose a single case-study design to gain in-depth insights into the organizational complexity considering its transformation processes and tensions and because of the study's explorative character (Gerring, 2007). To this end, we selected the case of the Dutch infrastructure organization Rijkswaterstaat to pursue becoming circular. Rijkswaterstaat is the Dutch infrastructure organization responsible for managing, constructing, and maintaining road transportation infrastructure, waterways, and flood protection infrastructure. As a directorate-general within the Ministry of Infrastructure, it acts as the executional body for national road and water infrastructure. The organization comprises seven regional branches responsible for managing local infrastructure, as well as national divisions for Information Management, Large Projects, Small Projects and Maintenance, Traffic Management, and Knowledge and Strategy. On top of its traditional responsibilities, Rijkswaterstaat is increasingly called upon by politics to address societal challenges and stimulate transformation. Circularity was top-down introduced in 2016 as a government-wide mission for 2030 and 2050, with separate attention for infrastructure since 2018 (Transitieteam Bouw, 2018). Most circularity-related initiatives were launched between 2016 and 2018 and started with strategic and technical explorations. However, since 2020, notable initiatives have been launched to change organizational processes and institutions. At the same time, the difficulty of implementing the strategies into the organizational and operational processes was widely echoed.

Rijkswaterstaat embodies various organizational identities, including engineering, management, and government (Termeer & Van den Brink, 2013). Employing almost ten thousand people, Rijkswaterstaat serves as the largest infrastructure client and owner of road and water infrastructure in the Netherlands. It plays a leading role in shaping domain-specific norms, policies, and networks, positing it as a key player and a frontrunner in driving the transition towards a circular infrastructure sector by other Dutch infrastructure clients. This role stems from Rijkswaterstaat’s pioneering efforts in implementing circularity principles in a public organization in the Netherlands (Schut et al., 2015). However, it is also characterized as a slow changer because of its large size and highly institutionalized practices. The circularity trajectory is particularly suitable to highlight the institutional pressures resulting from the tensions between the public nature of the organization and the market-driven construction processes in the infrastructure sector.

5.3.2 Data collection

Data for this study was collected from two primary sources. First, we conducted interviews with individuals from the different ranks and organizational units within the organization who either directly influence or are affected by the implementation of circularity. These included individuals from the various predefined institutional contexts, such as state, project, and sustainability. Moreover, since Rijkswaterstaat operates as the executional body of a Ministry, we included several interviewees on the interface between the Ministry and Rijkswaterstaat. Second, we collected various organizational documents on formal strategies, evaluations, and policy explorations related to circularity. These documents served to establish the formal structures, policies, and strategies required to transition towards circularity, thus providing important contextual information and formal processes. Moreover, these documents assisted in the selection process for our interviewees.

Table 14. Interviewees and their functions.

Code	*Function/role*	*Organizational unit*
LP1	Innovation programme manager	Large projects
LP2	Innovation programme manager	Large projects
LP3	Program manager	Large projects
LP4	Department head	Large projects
LP5	Portfolio manager	Large projects
LP6	Program director	Large projects
LP7	Project manager	Large projects
LP8	Program manager	Large projects
LP9	Program director	Large projects
LP10	Material expert	Large projects
RD1	Asset manager	Region
RD2	Department head	Region
KD1	Reuse manager	Knowledge and strategy
KD2	Department head	Knowledge and strategy
KD3	Policy advisor	Knowledge and strategy
KD4	Policy advisor	Knowledge and strategy
MD1	Policymaker	Internal client Ministry
EM1	General policy advisor	Executive staff
EM2	Sustainability policy advisor	Executive staff
CD1	Program director	Corporate

We employed a purposive sampling approach to ensure a comprehensive interview sample, explicitly targeting individuals in critical organizational positions (Campbell et al., 2020). Our selection process aimed to cover all organizational units and include representatives from various ranks, ranging from executive officers to project members. By adhering to these criteria, we initially identified twelve individuals based on the organizational structure and formal CE strategies. These individuals were involved in identifying other relevant participants who offered unique perspectives. Data saturation was reached after conducting twenty interviews using a snowballing technique to select interviewees. In the resulting set of interviewees (Table 14), many were highly experienced, had previously worked with circularity to some extent, and were considered either experts or powerful in their respective domains. The interviews were conducted using a semi-structured format, focusing on values, norms, practices, and roles pertaining to the functioning and transformation of the organization and its challenges in adopting circular solutions. This approach resulted in twenty interview transcripts of 8,000-13,000 words each.

5.3.3 Data analysis

The transcripts were both used to reveal the formal and informal processes of both the circularity implementation and infrastructure management using a prescriptive coding approach and to link motives of individuals to institutional logics using a first-cycle values coding approach and a second-cycle pattern coding to induce and define dominant logics (Reay & Jones, 2016; Saldaña, 2013).

First, processes were descriptively coded on the general organizational processes regarding the management and construction of infrastructure as well as the circularity implementation processes and development using ATLAS.ti software. This type of analysis allowed for a coherent understanding of the course of events to determine causality between the circularity and infrastructure management processes. This approach allowed us to identify interactions and potential tensions between the traditional infrastructure management processes and processes related to CE policies throughout the infrastructure management phases.

Second, considering that logics tell something about social structures yet are intangible per se, values coding was employed to find specific motives of individuals, eventually linking them to shared patterns. Because values are trans-situational (Kraatz et al., 2020), they can serve as a proxy for logics. As such, they pertain to specific aspects of perceived importance by the interviewees, ranging from individual values to values relating to specific practices. The values were used here to cluster quotations in the logics using pattern coding (Miles et al., 2013). After several iterative clustering steps, depending on both existing institutional logics literature and coded interview transcripts, four logics emerged: *state logic, project logic, asset management logic,* and *societal challenge logic*. By linking the codes to the interviewees and their position within the organization, we identified clusters of individuals that could be traced to particular organizational units and types of work, such as department managers, project employees, internal consultants, and programme managers. This allowed us to create links between logics, organizational structure, and organizational processes. These clusters were treated as the collection of individuals within the organization who largely draw from the same logics.

Using the empirical data and existing literature concurrently allowed for an increased understanding and coherence of logics (Van Maanen et al., 2007). After having bottom-up established the logic, these were linked to a list of critical characteristics based on Jay (2013), Jones et al. (2015), Farid and Waldorff (2022), and Thornton et al. (2012) distinguishing material structures from practices from immaterial ideation and meaning. The categories enabled us to construct ideal types from the empirically derived taxonomy of the logics identified, allowing us to use the taxonomy as an analytical framework to study tensions between circularity implementation and infrastructure management processes. The resulting list with the four ideal-type logics identified can be viewed in Appendix 5.1.

The relationship between logics and groups of individuals, such as project managers or policymakers, as well as the coded infrastructure and circularity processes, allowed us to study their interactions. This includes the interaction between individuals with similar and different guiding logics, the logics related to the infrastructure management process, and the logics related to the circularity concept and particular clusters. This allowed us to link the dominant logics in the various stages of the infrastructure management process to the circularity implementation process. This facilitated the identification of dominant, lacking, and opposing logics by examining how individuals from particular clusters performed circularity-oriented actions and how these actions were perceived and adopted by others. Our analysis revealed several recurring dynamics that highlighted tensions between clusters in terms of upscaling and institutionalizing circular norms, practices, processes, projects, and (technological) solutions in comparison with traditional infrastructure management processes, as well as deliberate strategies to introduce or align various logics in specific interfaces between circularity implementation and infrastructure management.

5.4 The circularity implementation process and related logics

Tensions between circularity implementation processes and regular infrastructure management processes are studied by determining both processes in terms of conflicting logics. First, we make an empirical account of the general infrastructure management and construction process in the organization under scrutiny. Next, the process of implementing circularity in the infrastructure organization is analysed. This approach allows for comparing and determining the tensions between the current infrastructure management practices and the circularity implementation process in terms of logics in the final subsection.

5.4.1 Organizational infrastructure management process

The interviews revealed that the management of infrastructure and project scoping of Rijkswaterstaat rests on highly institutionalized processes. Each regional unit is responsible for maintaining the proper functioning of existing infrastructure assets within their respective regions while adhering to nationwide requirements and policies. Although the interviewees from the regional units experienced significant autonomy (e.g., in terms of utilizing their own data and management systems), coordination activities do take place across the regions. The primary functions of the regions involve monitoring, minor maintenance tasks, and infrastructure network management. However, given their high pressures on budget and human resources and ambiguous goals, tough choices seem necessary between values, as illustrated by a regional asset manager (RD1): “A fixed budget is assigned to us to which we are limited, so if a particular circular solution increases costs, it will be nearly impossible to get it implemented.” When a functional or technical issue arises with an asset, the regional asset manager turns to the Ministry. The asset is added next to a list of assets requiring intervention, such as maintenance, replacement, or renovation. This is where the *asset management logic* intersects with the *state logic*, yet also where circular choices might play a role depending on the individual’s and the region’s priorities.

Based on centrally determined priorities, resources are allocated to the specific intervention and incorporated into the regional management contract through the executive staff in line with the *state logic*. This allocation process is strongly guided by a *state logic* as illustrated by a member of the executive staff (EM1): “It is up to the Ministry to consider how we spend the resources effectively, and they will always try to justify [these expenditures]. And we [i.e., Rijkswaterstaat] just implement this policy.” The interviews revealed that the ideas about values that should be prioritized differ strongly, not only between organizational units but even between individuals within units. After the resource allocation, the regional asset manager reaches out to one of the two project units within Rijkswaterstaat. They provide the project unit with context-specific requirements related to, e.g., spatial specifics, maintenance regimes and practices, network features, or desired interventions. Next, the project unit assigns a portfolio manager and establishes a project to execute the intervention, utilizing the allocated resources from the Ministry. Interviews indicated that these portfolio managers adhere predominantly to the *project logic* but also seem to bridge *the organization’s project and asset management logic*. In addition to the requirements from the regions, there are also requirements from the central client at the Ministry. These requirements appear to originate from standardized policy frameworks, budgets, and political priorities, which align with the political cycles and are predominantly shaped by the *state logic*.

After receiving input from the regional asset manager, the Ministry formulates the project scope. Subsequently, the portfolio manager from one of the project units assembles an integral project team to execute the project from an operational perspective, following a *project logic*. Here, it seems to depend on the individual whose priorities are allocated to projects, including aspects like circularity. The project team collaborates with individuals from various other units, including procurement experts, contract experts, technical experts, and occasionally sustainability and circularity advisors. Often, contracted consultancy and engineering work is involved for specific specialized tasks. During this phase, the project evolves from an abstract proposal into a detailed plan presented to the market. At this stage, specific solution directions or requirements related to circularity may be incorporated into the project if they are not already part of the formal project scope. In this context, the regions are in a leading role yet provide considerable leeway to market parties (RD2): "We leave a great deal of actual execution to market parties. When we need certain maintenance activities, we leave quite some room to manoeuvre to the market for selecting their preferred solutions."

Once the procurement process is completed, a consortium of market parties, typically led by a main contractor, undertakes the work in line with the *project logic*. These projects are unique and can span several years – even up to a decade. Introducing changes, including circular changes and additions, becomes increasingly challenging over time. Despite this being the space where actual circular solutions can be implemented, several interviewees argued that it is the least suitable moment to take the initiative for circularity, given the prescribed boundaries. Articulated by a project manager (LP7): "We receive the project scope imposed by the Ministry in an order form, including the project budget. […] If they think circularity is important, they will include it in the scope form, and we will execute it." Upon project completion, the asset is returned to the respective regional unit, which retains the asset management responsibilities for that specific asset. Figure 7 provides a visual representation of this cyclical infrastructure management process, illustrating the stages and the responsible units associated with the underlying logics of individuals in the units that influence each stage.

Figure 7 illustrates that decision-makers drawing from particular logics play a significant role in particular stages of the infrastructure management process. The hybridity involved has created an effective system capable of addressing contextual pressures (cf. Pache & Santos, 2021), ranging from political to market pressures. However, despite the suitability of this institutionalized infrastructure management process, the implementation of circularity principles within the organization has been limited thus far. In the following section, we will delve into the case-specific dynamics aimed at implementing circularity within Rijkswaterstaat, focusing on the specific efforts to integrate circularity principles into the existing infrastructure management process.

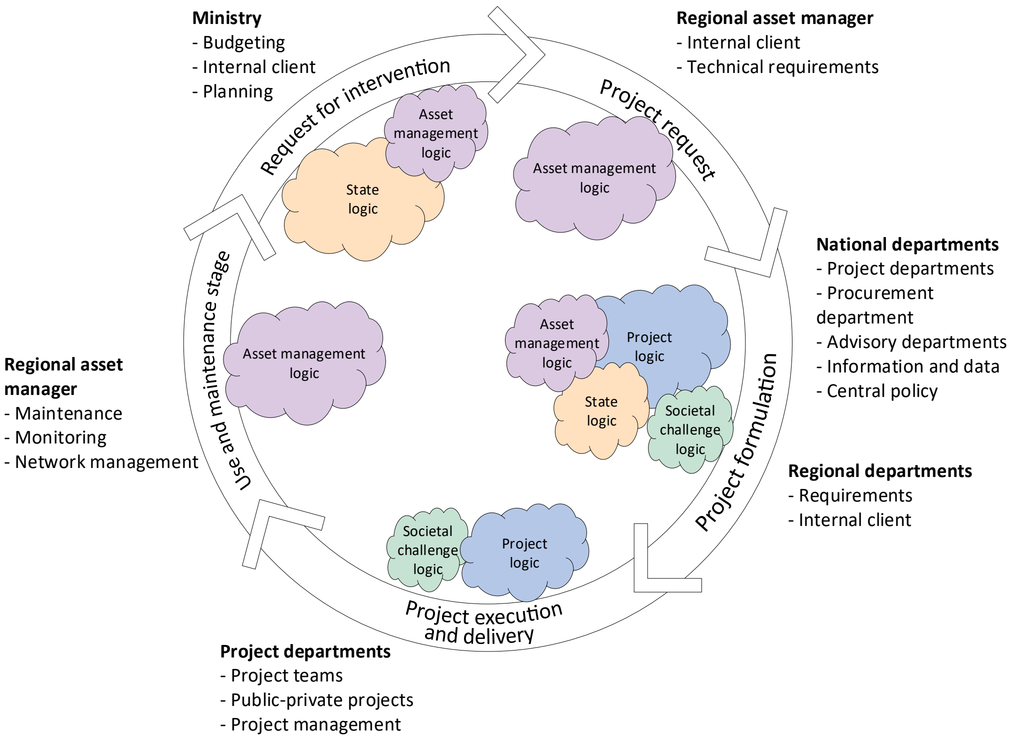


Figure 7. Asset lifecycle process coupled to dominant logics per phase.

5.4.2 The circularity implementation process

The initial circularity initiatives can be traced back to 2014 when a policy exploration occurred. However, it was only in 2016 that more structured approaches were launched. Three dominant approaches to implementing circularity, all guided by a distinct set of logics, can be distinguished. These approaches are linked to the logics that are dominant within them and are detailed below.

First, a circularity-oriented *knowledge programme* (KnowPr) was introduced to explore potential circular solutions and assess the impact of circular practices on the organization and the wider infrastructure sector. Strongly guided by idealism, individuals involved seemed to draw predominantly from the *societal challenge logic*, as revealed by the strongly sustainability-oriented interviewees. While the circular KnowPr had a significant stimulating effect on the organization as well as several infrastructure projects and the wider sector, the results were perceived by many as being too abstract and detached from practical application to upscale or institutionalize. As illustrated by a portfolio manager (LP5): “They [KnowPr] do important things on circularity, but at some point, it stalls at the strategic level. It often lacks the translation to our daily and operational practices.” Nevertheless, it played a substantial role in several increasingly institutionalized practices, such as procurement methods, design principles, and monitoring approaches.

Moreover, numerous pilot-scale explorations of circular solutions were conducted in project contexts, including an innovative approach to viaduct design and many of these pilot programmes were initiated or supported by the KnowPr. Nevertheless, the level of success was perceived ambiguously. A general observation by many was that these initiatives remained isolated regardless of their success and were not extensively scaled up. The achievement of practical application was often reported as the result of unplanned incidents and individuals sticking their necks out rather than being structured processes, procedures, or platforms. Here, it turned out to be difficult to insert practices that result from adhering to the *societal challenge logic* in a context where the *project logic* prevails due to the differing reasons to act of the respective individuals.

Simultaneously, a collaborative large-scale and cross-organizational implementation programme (ImpPr) was launched by Rijkswaterstaat, the Ministry, and the railway agency in line with the national mission for the Netherlands to be fully circular in 2050. Furthermore, this initiative was linked to several other sustainability-related goals. As stated in formal policy documents, the primary focus of this programme was to implement CE and sustainability goals set by the government in the infrastructure domain. The programme aimed to bridge the gap between abstract CE concepts and practical application, strongly emphasizing upscaling and institutionalization. Unlike the KnowPr, this ImpPr involved the broader organization, and interviewees revealed a more robust representation of the *project* and *asset management logics*. It was structured into four *transition pathways*, each led by a *transition pathway leader* responsible for prioritizing road pavement, coastline safety and dredging, civil engineering structures, and climate-neutral construction site and logistics, respectively. These transition pathway leaders all had a background in infrastructure practice and seemed to draw from either or both *asset management* and *project logics*. One even explicitly mentioned to “carry project DNA” (LP8). The transition pathways identified pathway-specific opportunities within projects to implement various circular alternatives. As illustrated by the KnowPr manager (KD2), there is an increasing link between the individuals working for the KnowPr and the ImpPr: “For years, the circularity programme […] was very divergent by nature […]. However, as a team, we are increasingly transforming from an explorative mindset to a demand-driven approach in relation to the formally designed transition pathways.”

Although the programme had neither a dedicated budget nor capacity, it placed significant importance on coordination and alignment, both internally and externally. By operating independently from the organizational line, it seemed to be able to connect with all layers and units within the organization. Recognizing the nature of the programme, the programme director stated on implementing fundamental organizational change for circularity (LP6): “I don’t believe in having a long-term strategy that is too predefined. You just can’t plan it. How it has proceeded so far within [Rijkswaterstaat] was highly determined by dynamics from outside.” While strategic documents and policies guided long-term goals and approaches, the programme heavily relied on identifying ad hoc opportunities within existing projects and adopted an adaptive governance approach.

Interviewees widely acknowledged that the current approach to implementing circularity is strongly dependent on individuals’ intrinsic motivation to take on the circularity challenge. For example, a project manager (LP7) of a project in which a circular measure was implemented stated: “After a while, everyone in the project team just went for it and dedicated additional time to execute it. […] It was not greenwashing, but they did it because they wanted it – and I like that.” Although circularity performance was not integrated into the general personal performance measurements, there seemed to be a strong belief within the organization that circularity is an important theme, leading to a considerable willingness to act in line with circularity principles. Nevertheless, when values relating to the historically prevailing logics (i.e., *project logic, asset management logic*, and *state logic*) conflict with CE, the latter tends to be eliminated, indicating an inability to adopt a paradox mindset.

When project members intended to include circularity, they reported struggling with determining where and how to start with circular solutions due to the perceived abstractness of the circularity-related knowledge, given their adherence to the *project logic*. As a portfolio manager argued (LP5): “Sustainability advisors are not able to put themselves in a project mode to translate the abstract ideas into concrete norms. […] Those two worlds just can’t understand each other. It is like the Tower of Babel – they speak different languages.” A circularity advisor (KD1) confirmed that this difference even exists within the group of sustainability advisors: “You can even see the difference with the project sustainability advisors. While we [knowledge department] are involved in an initial stage, they [project advisors] are involved in the contracting phase, and both represent a different mindset.”

There are several occasions in which specific individuals were decisive that did not draw from one specific logic but rather functioned as boundary spanners between groups that draw from specific logics. We refer to these individuals as *pioneers*. These pioneers turned out to play a decisive role in bridging the gap on various occasions where circular initiatives were successfully implemented or scaled up. Considering these factors, it can be concluded that despite the significant efforts made in knowledge development and the ImpPr, there is currently no structured process in place to institutionalize circularity within the organizational structure, processes, and practices.

5.4.3 Logic interaction in the pursuit of circularity implementation

By examining the interplay between the logics related to organizational infrastructure management processes and the implementation efforts of circularity, we identified potential tensions and assessed the organizational response in the studied case. Many observed circularity efforts are found within project execution rather than in the organizational processes that contribute to eventual project formulation. Specifically, tensions seemed to emerge in the asset use and maintenance stage when assets are managed by regional units. The contrasting logics turned out to account for the substantial gap between circular strategies and asset management practices, leading to difficulties in introducing circular asset management processes. A regional manager (RD2) highlighted this tension: “Our primary task is to ensure that the infrastructure is up and running and to ensure the availability and accessibility of the network. [...] Policy goals [such as CE] may suffer from this priority.”

Another tension arose during the formulation of the project scope, budget, and briefs, where individuals adhering to the *state logic* held influential positions. This perspective is exemplified by an executive staff member (EM2): “From all directions, there are appealing ambitions on circularity, and there are assignments to explore this, but that is different from an implementation agreement. Such an agreement requires that [the Ministry] formulates a clear task which the infrastructure organization should execute.” Confirming this, a regional head of district (RD2) explained the consequence of a lack of such agreements: “A top-down goal or definition is lacking, and it depends on individual management contracts per organizational unit how and to which extent circularity is included.” This quote illustrates the limited and fragmented inclusion of the *societal challenge logic* in the formal top-down project statement during this stage. To address this challenge, the ImpPr was intentionally established by the Ministry to connect the *societal challenge logic* with the *state logic* and exert influence over the project direction. However, for the KnowPr, it turned out to be more challenging, as a programme manager

(KD2) highlighted: "The Ministry is our formal commissioner, but we also receive requests from the internal project organization, which puts us in a straitjacket."

Concerning meeting the goals for implementing circularity, the most fundamental tension between the state logic and the societal challenge logic seemed to arise. While the former, which is adhered to by individuals who hold the most power, prescribes incremental policy cycles involving small processual changes that take several years each to be implemented, the latter was adhered to by interviewees who envision a transformative change in terms of culture, practices, and institutions. Despite their interdependence for achieving circular outcomes, a similar distance was perceived between the organizational units that predominantly drew from the *project logic* and the units that primarily drew from the *societal challenge logic*. Interviewees mentioned several instances in which this resulted in a lock-in situation, which indicates a risk that paralyzes circularity efforts in the shape of a waiting game and demotivated individuals.

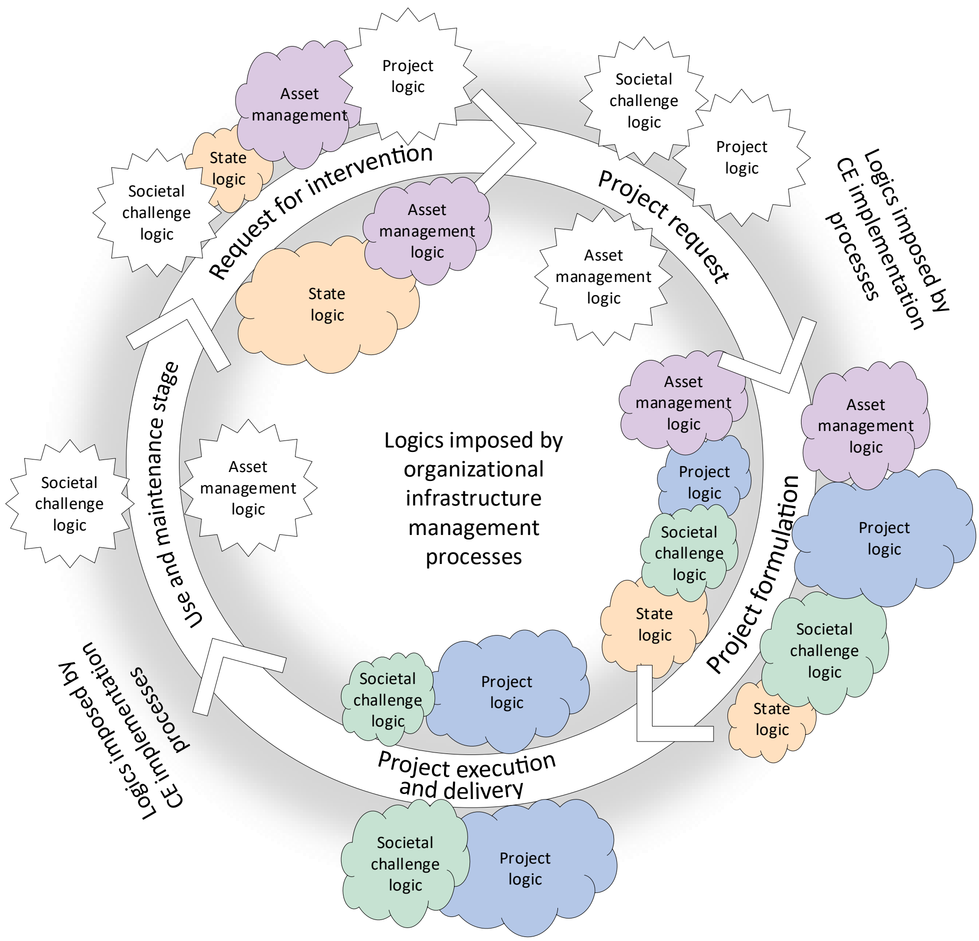
Individuals with the most intricate understanding of circularity appeared to be the ones drawing from the *societal challenge logic*. Nonetheless, these individuals held little power over the units that control the organizational processes. Acknowledging this power imbalance, these units increasingly aimed to align their efforts with the *project logic*. Nevertheless, the decision-makers guided by the *state logic* did not consider themselves in the position to compromise between existing values and the values that underlie a CE. After all, their understanding of the role of the public infrastructure organization in the transition towards circularity differed fundamentally from *societal challenge logic*-lead individuals. While, according to the interviews, the purpose of executional governmental bodies following the *state logic* was to guarantee continuity of public service delivery, individuals drawing from the *societal challenge logic* seemed to consider public organizations as leaders of addressing challenges that serve society at large beyond the execution of policy assignments.

When considering the infrastructure management cycle, we found that the *state logic* and the *societal challenge logic* barely interact in the initial stages of the process. Related to the asset management stage, individuals adhering to the *asset management logic* expressed limited awareness of and knowledge about the potential alignment between circularity principles and asset management. As a result, the regional units guided by the *asset management logic* seemed to have not yet successfully integrated circularity principles into their activities despite the efforts of multiple individuals from the regional units and the knowledge department. A strategy mentioned to address this gap was the mobilization of logic-bridging individuals. Efforts from these pioneers, as mentioned before, were often directed towards high-risk and innovative initiatives. Although there are several efforts in which these individuals have brought the *societal challenge logic* together with the *project logic* in a circular pilot project, the efforts mentioned by interviewees have so far not been directed towards and hence not led to fundamental circularity implementation in the organizational structure. While some perceived changing the structure as a scrupulous yet feasible process, others deemed such change sheerly impossible, particularly in the regional and project units.

In conclusion, the organizational goals, aligned with the concept of the CE, create institutional demands that necessitate organizational responses consistent with the relevant logics. While the studied organization has established new units, programmes, and fora encompassing these logics, it has been observed that alignment with the dominant logics in existing processes remains deficient despite considerable progress in specific projects or solution directions. Consequently, interviews in Rijkswaterstaat revealed considerable efforts to bridge the gap between different logics (*project logic*, *asset management logic, state logic*, and *societal challenge logic*) within the organization to implement circular practices. Notably, the ImpPr was initiated involving individuals from various units associated with different logics. Although this approach seemed to initiate transformative processes, interviewees faced fundamental difficulties in fully integrating these conditional processes and institutions into its core related to the infrastructure management processes. This challenge seemed to be particularly problematic in the context of circularity. In this context, infrastructure practices and outputs aligned with circularity principles turned out to be heavily influenced during the initial stages of the infrastructure management process, including planning, budgeting, and scope definition. The interactions between the infrastructure management processes and circularity implementation processes are illustrated in Figure 8.

5.5 Discussion

This chapter aims to increase the understanding of how an infrastructure organization pursues the systemic circularity transformation while maintaining its business operations. Using an institutional logics lens, we identified four prevailing logics (*state logic, project logic, asset management logic*, and *societal challenge logic*; Appendix 5.1) that interact with each other in specific parts of the organizational processes. First, we discuss how logic interaction can both hinder and enable change in public infrastructure organizations, followed by a reflection on the implications of our findings for theory and practice.



*Star-shaped boxes illustrate conflicting logics at the respective stage between the conventional organizational processes and the circularity implementation processes.

Figure 8. Interaction of logics per infrastructure management stage.

5.5.1 *Logic interaction in the pursuit of a circular infrastructure organization*

The examined organization operates within a pluralistic institutional environment, necessitating the integration of prescriptions from multiple distinct institutional logics to establish legitimacy for its activities (Perkmann et al., 2019). Given the dominance of specific logics in particular organizational units, the case organization can be characterized as a structural hybrid (Raynard, 2016). The identified logics include the *state, asset management, project*, and *societal challenge logics*. This diversity of internal logics significantly impacts the infrastructure organization's endeavours to adopt circularity principles, exerting both enabling and constraining effects on its role in the transition.

As an enabling aspect, the multiplicity of internal logics empowers the infrastructure organization to address functional and technical aspects linked with circular practices concurrently. This is achieved through the frameworks of *asset management logic* and *project logic*, while upholding a high degree of transparency and proceduralism as prescribed by the *state logic* during the initial budgeting and planning phases of projects. Within these boundaries, organizations can incorporate circular solutions in a project environment. The coherence between these logics is maintained mainly by well-established governance structures and decision-making processes that have historically evolved between the infrastructure organization, the relevant sector, and the Ministry. To navigate the intricate complexity, the organization employs federated governance structures (Raynard, 2016), exemplified by semi-autonomous regions and operational settings within projects and programmes. Nonetheless, suppose these governance structures or decision-making processes fail to adapt to new or unconventional developments, such as the introduction of circularity. In that case, it can result in the introduction of and misalignment between logics, increasing the institutional complexity characterized by conflicting prescriptions (Greenwood et al., 2011).

An illustrative instance of logic misalignment involves the creation of a dedicated cross-organizational programme, which incorporates individuals representing diverse logics. This programme played a pivotal role in bridging the gap between these logics and translating concepts into tangible projects and organizational workflows, effectively expediting institutional transformation in line with Jay (2013). However, the simultaneous establishment of this programme alongside the organizational hierarchy led to limited authority over core processes, complicating the integration of circularity into operational practices. A key factor here is the challenge of reconciling circularity principles, inherently oriented towards long-term systemic change and addressing societal issues (Aarikka-Stenroos et al., 2021), with the *project logic's* task-driven, time-constrained nature, as well as the short-term political cycles guiding the *state logic*.

Conversely, the multiplicity of internal logics acts as a hindering aspect by triggering adverse outcomes when not appropriately managed, encompassing inadequate organizational performance (Mair et al., 2015), organizational fragmentation (Greenwood et al., 2011), and organizational paralysis (Pache & Santos, 2021). Such repercussions arise when organizational contexts fail to address multiple institutional demands (Kraatz & Block, 2008). Particularly since the introduction of circularity increases pressures on the available resources in terms of funding and time is a source of tensions, individuals are forced to cope with these tensions, which were, in our case, often left unattended due to a lack of paradox mindset (Miron-Spektor et al., 2018). Findings indicate that when the infrastructure organization confronted new societal imperatives for transitioning to the CE while bound by historical, project-specific requirements for efficient service delivery to the public sector, one set of demands undermined the other. The results reveal that although formal demands to transition to the CE were issued by the Ministry, the actual implementation of circularity principles within the organization heavily relied on individuals' intrinsic motivation. However, these individuals hold limited power in implementing circularity principles across different organizational units, as the organizational processes are tailored to suit conventional project needs. This discrepancy is sustained by organizational fragmentation and the divergence of the ideas of CE objectives and definitions (Denis et al., 2015). Hence, the variation goes beyond mere logic multiplicity; it extends to distinct approaches to organizational structure (e.g., vertical hierarchy vs. flat hierarchy) and how circularity is framed in the organizational context.

This friction underscores the close interdependence between organizational structural changes and adapting to new institutional demands (Ocasio & Radoynovska, 2016), ultimately emphasizing the necessity of reconsidering the organizational structure to embrace circularity fundamentally. An opportunity to effectively employ logic plurality could, for example, involve embedding individuals from the knowledge department guided by the *societal challenge logic* in the projects or the asset management processes to connect institutional demands for the CE with the infrastructure management demands to connect the external pressures to the internal processes and practices to purposefully create a blended (or assembled) hybridity (Raynard & Greenwood, 2014). Another approach would be the deliberate development of ambidextrous leadership skills to deal with paradoxes that result from the institutional plurality imposed by circularity (Miron-Spektor et al., 2018; Smith & Lewis, 2012).

5.5.2 Implications for theory and practice

While the existing body of literature acknowledges three out of the four identified logics (e.g., Corbett et al., 2018; Farid & Waldorff, 2022; Frederiksen et al., 2021; Schraven et al., 2015), the *societal challenge logic* was newly introduced. Although it resembles the *sustainability logic* introduced by Greenwood et al. (2015) and Olesson et al. (2023), our findings show that sustainability does not encompass the entire spectrum of values stakeholders uphold. Similarly, the *circularity logic* (cf. DiVito et al., 2022) falls short of fully encapsulating these values due to the incipient institutionalization of circular practices, which are best comprehended as contextually driven practices or ideologies that draw from multiple logics and broader developments (Jarzabkowski et al., 2015; Mountford & Cai, 2023). While sustainability and the CE are central topics of focus within the case, the term 'societal challenge' is deliberately used instead to encompass a broader range of societal issues rather than singular topics such as climate change or resource depletion (Gümüsay et al., 2020). In addition, the terms 'sustainability' and 'circularity' are often interpreted in contested and narrow ways (Korhonen et al., 2018). These faulty interpretations instigate a risk of misinterpretation when labelling the logics accordingly. Therefore, we position the *societal challenge logic* as a construct derived from the moral responsibilities of adherents to contribute to society over the long term, striving for maximal societal impact without being tied to specific substantive content. Consequently, adherence to and utilization of this logic exhibit adaptability and responsiveness to evolving societal challenges. Hence, it is not imperative for the entire organizational framework to align with the *societal challenge logic*; instead, its inclusion surfaces when societal pressures mandate organizational transformation (cf. Narayanan & Adams, 2017).

Our findings highlight the systemic character of circularity necessitating transformative measures in public infrastructure organizations. In contrast to private counterparts, the transformation in public organizations is not primarily linked to fundamental business models. Instead, it centres on fostering market conditions that facilitate circular behaviour by private parties, particularly relevant at the meso level (e.g., industrial systems) and macro level (e.g., societal systems) (Svensson & Funck, 2019). This market orientation provokes reimagining the roles of both public entities as lawmakers to introduce incentives for circular market progression and as procurers to prioritize the acquisition of circular solutions (Witjes & Lozano, 2016). Nonetheless, our findings also underscore that taking responsibility for procured goods entails assuming responsibility for asset management, necessitating systemic shifts to attain high-level circular strategies for infrastructure assets, such as extending lifespan or minimizing resource consumption in terms of organizational output (Chapter 2; Potting et al., 2017).

Lastly, the public nature of the organization brings forth characteristics that significantly influence its capacity to navigate organizational change in alignment with emerging institutional pressures (De Waele et al., 2015). Most prominently, the *state logic* that guides the organization's management directly stems from its role as an executive body of the Ministry. Beyond the organization's internal potential for change, this logic impedes the incentive to collaborate and share responsibilities with external entities, often of a private sector nature, that are crucial for addressing societal challenges (Eneqvist, 2023). Although managerial and market-driven strategies have been introduced in the public sector to more efficiently and effectively respond to evolving institutional demands, this necessitates a re-examination of the role of public organizations in tackling transitions, e.g. CE, touching upon the legitimization of public organizations as enablers of societal transformations (Braams et al., 2021).

5.6 Conclusions

Public infrastructure organizations play a crucial role in the transition towards a CE because of the substantial amount of material resources they manage. Achieving circularity within these inherently hybrid organizations necessitates comprehensive overhauls across organizational structure, processes, practices, and institutions. This study delved into the impact of logic multiplicity on the progression of public organizations towards a CE, revealing both impeding and enabling effects on implementation endeavours. The institutional logics lens enabled us to investigate how various institutional frames, followed by individuals, assist the organization in addressing multiple externally imposed institutional demands within their operational activities. Simultaneously, this lens also allowed us to delve into how complexity gives rise to tensions when a new institutional demand, necessitating transformative change within the organization, is introduced. The results reveal multiple challenges public infrastructure organizations face in transitioning towards a CE.

Although the organization under study has made commendable advancements in specific projects and solution directions, a noticeable misalignment persists between the prevailing institutional logics governing infrastructure management processes and those associated with circularity objectives. Notably, our findings indicate that the practices and outputs linked to circularity principles within the organization are shaped during the preliminary phases of infrastructure management, encompassing planning, budgeting, and scope delineation. In contrast, most circularity efforts are predominantly exerted in the stages of designing and project execution, where the room to manoeuvre is limited.

Moreover, the hybrid nature of public organizations entails the navigation of various logics to address distinct institutional contexts such as politics and the market. Related to circularity initiatives, we identified a logic that individuals within the organization employ: the *societal challenge logic*. While the intersection of historically prevailing logics with the societal challenge logic yielded notable successes in circularity implementation, conflicts between logics emerged primarily in connection with asset management and planning processes. These conflicts impede a seamless integration of circularity principles into organizational practices, particularly those integral to determining how infrastructure assets are managed, interventions are planned, and conditions are stipulated. The inherent incompatibility between the *societal challenge logic* and the *state logic* prevalent in public organizations underscores the importance of clear and coordinated directives from decision-makers to align organizational aims with circularity principles. This direction calls for an open debate in the organization on the role of government as well as the role of Rijkswaterstaat as an executive body of the Ministry and how these two either conflict with or complement each other.

Attempting to embed circularity solely through hybridity seems unfeasible due to the entrenchment of conventional logics within public organizations. In other words, individuals in the organization revert to old practices since circular practices are not institutionalized yet. Therefore, decision-makers, particularly politicians and senior-level public servants, must provide unambiguous directives to shape organizational goals. This approach ensures the assimilation of goals into the task specifications of public servants following the *state logic* and *asset management logic*, ultimately resonating down to project teams. The early engagement of circularity experts, guided by the *societal challenge logic*, in organizational processes emerges as an essential practice. While the organization's expertise can offer guidance, the transformation towards a circular system primarily hinges on the desired organizational outcomes.

These findings are anticipated to apply beyond the geographical context of this study and the specific organizational domain due to the inherent hybridity and partial adherence to *state logic* characterizing public organizations. Given that the *state logic* is dominant in decision-making in many public entities, similar dynamics are anticipated to manifest when these organizations strive to operate and produce outputs aligned with circularity principles.

5.7 Limitations and future research

This study is not without limitations, offering avenues for further exploration. First, the analysis rests on interviews conducted within a single organization. While the case organization exhibits intriguing ways of harnessing hybridity for circularity implementation, diverse public organizations will likely adopt varying approaches, yielding distinct outcomes. Consequently, the logics identified in the organization might be more strongly associated with ideologies or situated practices, demanding research in other public and infrastructure settings outside the Netherlands.

Moreover, this study focuses on CE strategy input rather than circular solution output. In line with the call of Pinkse et al. (2023), this presents an opportunity for research into the tangible solutions applied in infrastructure, offering a crucial perspective on the efficacy of organizational strategies in addressing particular challenges underlying the CE. Given the evolving and contested nature of circularity, discerning the point at which a public organization truly embodies circularity poses challenges. Continuous research efforts are thus imperative to comprehend the interplay between organizational processes and circularity principles, particularly given the evolving nature of circularity. Employing longitudinal data collection methods, including ethnographic approaches, could provide a more dynamic view of implementation processes and potentially unveil additional and more detailed logic interactions (e.g., Bévort & Suddaby, 2016) and nuanced action perspectives that can catalyse the transition.

Additionally, we introduced the *societal challenge logic* as a construct encapsulating the moral responsibilities of adherents towards long-term societal benefit, embracing the entire range of values upheld by those involved in and beyond the circularity transition. For being intentionally designed to be normatively neutral, examining its applicability to broader logic interactions in other organizational contexts necessitates further exploration and theoretical refinement, for example, by relating it to transformative missions (Janssen et al., 2021) or grand societal challenges (Gümüsay et al., 2020). Smith and Tracey (2016) suggested that a paradox theory lens might offer a suitable framework to theorize the heightened complexity stemming from institutional demands rooted in societal challenges. Lastly, the influential role of boundary-spanning pioneers, mediating between logics and facilitating interaction, has been pivotal in implementing circular solutions. Delving deeper into their methods and functions, for example from a boundary-spanning perspective (Nederhand et al., 2019), within the transformation process could serve as a promising avenue for further research, shedding light on their potential and limitations in shaping future organizational transformation endeavours.

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chapter 6

collaboration and innovation beyond project boundaries: exploring the potential of an ecosystem perspective in the infrastructure sector

Abstract: Current societal challenges demand enduring engagement and the implementation of innovations. Unfortunately, the project-based nature of the construction industry fails to offer suitable conditions for innovation and change in terms of building long-term relationships and aligning incentives beyond the project scope. In this chapter, we explore the potential of an innovation ecosystem perspective to reach sector-wide goals related to societal challenges in the infrastructure sector. Accordingly, five Dutch infrastructure cases were studied in terms of four characteristics: (1) actor heterogeneity; (2) strategic alignment of actors; (3) alignment with respect to a value proposition; and (4) governance structure. We found that the innovation ecosystem perspective has the potential to contribute to innovation in the sector, especially when specific innovations or knowledge-building are pursued. In particular, the long-term perspective on collaboration in relation to addressing societal challenges and the shift to more relational ways of governance were found promising avenues for incorporation in the industry. The innovation ecosystem perspective in infrastructure, however, also poses substantial organizational, cultural, and processual challenges, such as adopting novel practices for collaboration and establishing continuing informal relationships beyond the public procurement context.

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Coenen, T.B.J., Vosman, L., Volker, L., & Visscher, K. (2021). Projects as temporal configurations within innovation ecosystems: evidence from the construction industry. 37th EGOS Colloquium

6.1 Introduction

Project-based sectors, such as the construction industry, struggle with the temporal complexities that hamper collaborative action in response to societal challenges (Hilbolling et al., 2021). The traditional, project-based management approaches do not seem to accommodate the changes needed to scale up innovations and move towards higher levels of change (Martinsuo & Hoverfält, 2018). Existing approaches insufficiently exploit the benefits of interacting across projects collaboratively and over time (Bygballe and Ingemansson 2011). Melander and Pazirandeh (2019) even claim that a systemic transformation of the construction sector is needed, implying a reconsideration of relationships and activities within and beyond the traditional construction supply chains towards a more collaborative approach.

Construction management scholars increasingly explore novel approaches to overcome the issues of temporality that hinder innovation and collaboration in a project-based environment. Some of these approaches focus on supply chain integration (Kesidou & Sovacool, 2019), while others look at collections of parallel and sequential projects under the heading of project ecologies (Hedborg et al., 2020), public-private partnerships (Carbonara & Pellegrino, 2020) or collaborative procurement delivery models such as early contractor involvement and alliancing (Hällström et al., 2021). However, these approaches do not offer the conditions required for multiparty innovation towards goals that lay beyond the benefits of single projects, such as climate change and circular economy (CE).

In this chapter, we aim to explore the organizational innovation ecosystem perspective to address the issues of temporality and fragmentation in relation to collaboration in the infrastructure sector. In doing so, we follow the suggestion of Volker (2019, p.20) to "look outside the frames we are familiar with" and make use of concepts that originate from other research fields in studying fundamental issues related to construction management. We use the innovation ecosystem concept as a lens to identify and increase our understanding of the implications of collaboration beyond single projects and innovation processes in a construction setting.

The innovation ecosystem perspective has been widely applied in the literature on organizing innovation in industrial sectors and offers a broad perspective that is not limited to dyadic relationships and existing ties between actors (Ritala et al., 2013). Instead, it focuses on aligning the actors in a venture towards the shared value proposition to be realized (Shipilov & Gawer, 2020). Innovation ecosystems comprise constellations of actors and flows of value, information and resources that reach beyond single endeavours and niche innovations, and accordingly provide inherently a network perspective (Pel et al., 2020).

Apart from a few studies in construction related to single large projects or networks (e.g., Davies et al., 2014, Pulkka et al., 2016, Pelton et al., 2017), the innovation ecosystem perspective has, to our knowledge, not yet been studied systematically to reveal its potential for cross-project innovation in the specific context of infrastructure projects, such as the development and maintenance of bridges, tunnels and roads. Therefore, this chapter aims to explore the potential of adopting an innovation ecosystem perspective in the infrastructure sector. We pay specific attention to the ability to overcome complexities related to the temporariness of collaborative relations that stem from the project-based structure of this sector. As such, we aim to offer an alternative view to collaboration for project-transcending innovation that equips the sector with a starting point to address the emerging societal challenges that go beyond the scope of single projects.

First, we introduce the innovation ecosystem concept in Section 6.2, followed by a discussion of the structure of the infrastructure sector and its struggles concerning addressing project-transcending goals and innovations in Section 6.3. Next, we build on this innovation ecosystem perspective in Section 6.4 by creating a conceptual framework to analyse cases in the infrastructure sector. Section 6.5 explains how this framework is applied to five cases in the Netherlands and the results are presented in Section 6.6. The overall potential of the innovation ecosystem perspective based on the case results in discussed separately in Section 6.7. Finally, we present a discussion is Section 6.8 and conclusion in Section 6.9. In this final part, we present implications for infrastructure practice and construction management research and, based on the case results, provide suggestions for further research on overcoming the barriers to project-transcending innovation and collaboration in the infrastructure sector and beyond.

6.2 The innovation ecosystem perspective

In this chapter, we adopt an analytical approach to ecosystems and use it as a perspective to rethink the infrastructure system concerning change and innovation. As such, we exploit its ability to reveal complexities related to the temporariness of relations and collaboration that stem from the project-based structure (e.g. Vargo et al., 2020). Since the late 1990s, the ecosystem perspective has been recognized as a way to understand organizational systems by emphasizing the interactions between system elements and their context (Tsujimoto et al., 2018). In this section, we introduce the main theoretical principles of the innovation ecosystem concept to set the ground for the application of the innovation ecosystem perspective to the infrastructure sector.

6.2.1 Ecosystem types

Despite the wide variety of ecosystems in literature, the most researched types of ecosystems used in management literature are innovation ecosystems, business ecosystems, and platform ecosystems (Jacobides et al., 2018). Whereas innovation ecosystems aim for value *creation*, business ecosystems aim for value *capture* (Gomes et al., 2018). Because of this focus on value capture, business ecosystems include the end user for which a network of companies collaborates to address the end user's needs (Clarysse et al., 2014). Platform ecosystems, contrarily, are characterized by a central platform which connects organizations via shared technologies or standards (Jacobides et al., 2018). Here, complementors can create particular capacities or products that enhance the platform's value offering (Thomas & Autio, 2020), and gain access to the platform and its customers, e.g. in videogame development (Ozalp et al., 2018). Innovation ecosystems generally entail development and innovation activities characterized by a high level of interdependence and co-creation of value (Ketonen-Oksi & Valkokari, 2019). Because of the focus on achieving change and innovation, we specifically adopt the concept of innovation ecosystems in our study to look at project-transcending structures that stimulate sector-wide collaboration and innovations.

6.2.2 Conceptualizing the innovation ecosystem

Innovation ecosystems are constructed around central value propositions (Ritala & Almpanopoulou, 2017), which are described by Adner (2016) as promises or visions of new value that the combined efforts of the actors involved aim to create. This provides a useful perspective to reveal the collaboration required to innovate because it not only considers formal relations, but also "new possibilities to operationalize the environment" (Gomes et al., 2018, p.42). Actors in this environment include complementors, end-users, research scholars and policymakers, who generally fall outside the scope of both the traditional supply chains and the network perspectives that are applied in construction. Additionally, innovation ecosystems may involve unconventional actors, such as suppliers of technologies, specialized advisers or suppliers of knowledge or products from other sectors. At the same time, the reach goes beyond single projects, formal relations and industry boundaries (Ketonen-Oksi & Valkokari, 2019). Consequently, the innovation ecosystem perspective promotes co-creation and enables value to be created beyond what a single firm could achieve on its own (Smorodinskaya et al., 2017).

Innovation ecosystems typically exhibit high levels of actor heterogeneity (Thomas & Autio, 2019). Hence, they are not necessarily limited to sectoral boundaries, and consequently, innovation ecosystems might extend to cross-industry networks. System boundaries of innovation ecosystems are defined by a shared purpose, or at least interdependencies among organizations for creating value. Within well-functioning innovation ecosystems, there is a mutual agreement among participants on the positions and activity flows within the system (Adner, 2016). This involves not only the participants' positions regarding the value proposition but also the configuration of roles and activities within the system. Nevertheless, the actors, their roles and their interlinkages within the network may change over time, resulting in a dynamic network in which actors coordinate and complement their inputs to the value proposition (Valkokari, 2015). The participant heterogeneity displayed by innovation ecosystems is hence broad and transcends the boundary between the public and private sectors (Thomas & Autio, 2020).

Given the acknowledgement of interdependencies, actors within the innovation ecosystem may entail both collaborative and competitive relationships, which can result in a coopetitive structure (Bacon et al., 2020; Moore, 1993). Coopetition can be understood as collaboration between actors that operate in each other's competitive areas through incentive alignment, creating interdependencies between the involved organizations (Eriksson & Laan, 2007). These interdependencies emerge as actors depend on each other's success concerning the value proposition and can be viewed from a technological perspective (in case of co-specialization), an economic perspective (when interdependencies occur in capturing financial gains), a cognitive perspective (due to social rules or assumptions), or a combination of these (Adner & Kapoor, 2010; Thomas & Autio, 2020). To deal with these types of interdependencies, actors in innovation ecosystems develop strategies to align their innovation and collaboration processes to establish their position within the network (Visscher et al., 2021).

Such predefined goals for output are defined as value propositions. Innovation ecosystems are centred around one or several focal value propositions. Complementary activities by the different actors are required to realize the envisioned value propositions (Adner, 2016). Apart from innovations in the form of novel products or processes, even novel business models can be pursued as outputs of innovation ecosystems (Autio & Thomas, 2018). In business model innovations, participation in the innovation ecosystem that introduces new ways to create, deliver and capture value creates a competitive advantage over actors outside the innovation ecosystem. Together, a diverse combination of stakeholders incorporates a wealth of ideas, views, and knowledge, which is particularly useful when exploring novel problems and seeking solutions while maintaining a wide solution space. As such, the output of innovation ecosystems is both unpredictable and beyond the capacity of a single actor yet shared among actors. Regarding value propositions, one can distinguish the explorative layer which aims to identify opportunities for value creation, from the exploitative layer which aims to capture value from such novelties (Visscher et al., 2021). While the exploitative layer can be viewed on a project level, such as mega projects presented by e.g. Whyte *et al.* (2016), to find novel ideas and solutions the explorative layer requires relationships beyond the project scope – both regarding time and regarding actors and relationships. When aiming for value propositions in line with the emerging societal challenges, activities take place in the explorative layer.

The general relationship structure of innovation ecosystems can be characterized by different actors that provide complementary parts of innovations, products, or services, which are not necessarily bound by contractual arrangements. The strictness of the requirements for participating in an innovation ecosystem varies from basic rules to strong control and formal agreements (Jacobides et al., 2018). In innovation ecosystems, there is a significant interdependence between actors' inputs. Here, a relatively informal governance approach allows participants to take on dynamic roles in the venture towards delivering the value proposition (Jacobides et al., 2018; Valkokari, 2015). This relatively informal and dynamic structure blurs the system boundaries, which can be particularly challenging in public contexts due to legislative barriers (Phillips & Ritala, 2019).

Finally, innovation ecosystems are often orchestrated by a central actor that manages processes within the network and their effects on network innovation output by mobilizing knowledge, facilitating value appropriation and ensuring network continuity (Dhanaraj & Parkhe, 2006). Although influential, this orchestrator does not necessarily control or manage the innovation ecosystem itself (Phillips & Ritala, 2019). Instead, both the contractual conditions and the governance and control mechanisms in place may induce formality in innovation ecosystems. Depending on the preconditions, actors might change their involvement in terms of intensity, period, and relationships. As a result, value propositions, actors, relations, institutions, legislation and the contextual environment co-evolve (Gomes et al., 2018).

In conclusion, innovation ecosystems can be understood as heterogeneous sets of interdependent actors in a network that exhibit low levels of formality and in which outcomes are produced that are beyond the capacity of individual actors. To explore the potential of the innovation ecosystem perspective for the infrastructure sector, we first introduce insights into the current dynamics and barriers to project-transcending innovation in the infrastructure sector.

6.3 Barriers to innovation in the project-based infrastructure sector

Current societal challenges, such as the energy transition and a circular economy (CE), require different parties to collaboratively develop innovative solutions that could also move beyond projects (Ferraro et al., 2015; George et al., 2016). In infrastructure, however, value is typically created in publicly commissioned individual projects consisting of temporal organizations with multiple stakeholders (Olander & Landin, 2008). In this context, the fragmented nature of the infrastructure sector hinders the creation of societal value (Bygballe & Ingemansson, 2014; Håkansson & Ingemansson, 2013), as knowledge and capabilities are increasingly dispersed among organizations (Ahuja, 2007; Rutten et al., 2009). We refer to collaborations and outputs that are a consequence of thinking beyond projects as “project-transcending”. Barriers to project-transcending innovation in infrastructure mainly originate from the project-based structure of the sector on the one hand and the publicness of the domain on the other hand.

6.3.1 Barriers originating from a project-based industry

Like any project, infrastructure projects are characterized by fixed goals and task specifications, with predefined timescales and budgets. These projects often embody poorly aligned relationships between the actors, including public clients, contractors, engineering firms and suppliers involved (Flyvbjerg et al., 2009). At the same time, however, project participants are simultaneously embedded in multiple organizations and inter-organizational networks that are aligned for organizing various projects (Manning, 2008). As a result, infrastructure projects are inherently relational and embody interactions that contrast with their contextual conditions (Fuentes et al., 2019). This competitive and inflexible nature of the sector’s structure impedes the achievement of the changes and innovations necessary to address societal challenges such as climate change and urbanization (Dulaimi et al., 2002; Rutten et al., 2009).

Another complicating factor is that projects have separate phases in which different organizations collaborate. Such projects are treated as unique, temporary phenomena (Sheffer, 2011). Moreover, varying organizational structures of supply chain actors hamper the introduction of novelties in the work practices (Harty, 2005). Specifically, innovations do not only comprise novel combinations of materials but also unique combinations of processes and organizations, such that successful innovations, particularly in the context of diffusion, need to go beyond project boundaries (Rutten et al., 2009). Consequently, during the development of innovations, organizations could benefit from developing collaborative pathways that connect individual projects and go beyond collaborations bounded by project temporalities (Manning & Sydow, 2011).

6.3.2 Barriers originating from operating in a public domain

Many other persistent challenges to inter-organizational innovation in infrastructure projects stem from the fact that most physical infrastructure has public asset owners and needs to be procured according to regulations that impact the public-private relationships (Siemiatycki, 2011; Kuitert et al., 2019). These rules and regulations are primarily aimed at transparency and openness, creating a fair level playing field when spending taxpayers' money. Single-project tendering processes prevent long-term collaboration and often go hand in hand with strict dyadic contractual arrangements in which informal social ties are structurally neglected (Hällström et al., 2021). While in other construction domains, like housing, clients are often private entities allowed to initiate and continue relationships with their suppliers based on a strategic portfolio focus, procurement practices in infrastructure largely shape market conditions that impede cross-project diffusion of knowledge and innovation (Lundberg et al., 2019). This, moreover, hinders innovation in technical resources (Bygballe & Ingemansson, 2011; Larsson et al., 2014), for example, in the case of achieving circularity through standardization and prefabrication (Anastasiades et al., 2021).

6.3.3 Enabling project-transcending innovation in construction

Complex networks of stakeholders and long-term endeavours are required to overcome structural barriers to continuous, inter-organizational innovation from a project-transcending perspective (Martinsuo & Hoverfält, 2018). These types of innovations can be approached from different perspectives on collaboration in a construction context. For example, Hedborg and Karrbom Gustavsson (2020) take a project ecology perspective, which enables them to study interdependencies and interactions of actors performing projects close to each other within an urban district. Here, a positive effect on developing innovation processes was found for performing and managing projects both in parallel and sequentially. Other scholars, like Manning (2010) and DeFillippi and Sydow (2016), take a project network perspective to study innovation through inter-organizational relations between project participants from previous collaborative projects and practices that extend the single project.

So far, the innovation ecosystem perspective has remained rather unexplored to enhance multiparty innovation in project-based industries. Known applications of the ecosystem perspective in a construction context mainly consider a single mega-project as an ecosystem (e.g., Davies et al., 2014;

Pelton et al., 2017), or demonstrate the applicability of the concept centred around a collective of actors in a multi-project setting (Pulkka et al., 2016). In most of these studies, the project itself still plays a leading role.

Inspired by the innovation ecosystem concept, we argue that conditions for innovation could improve by focussing on relations around a central value proposition that is broader than a project or a central actor. Hence, this chapter introduces the innovation ecosystem as a perspective for understanding inter-organizational collaboration and innovation for emergent societal challenges beyond the project scope. To provide a framework for analysing infrastructure cases, we will next explain the application of the key features of this perspective to the infrastructure context.

6.4 Conceptual framework

In line with Thomas and Autio (2020), we position the value proposition in this research as a focal point to explore the potential of the innovation ecosystem for addressing project-transcending societal challenges. Based on the exploration of innovation ecosystems literature in the previous sections, we distinguish four characteristics of innovation ecosystems as identified by Thomas and Autio (2020), and adapt these to match the structural elements relevant to collaboration and innovation in the infrastructure sector. This leads to the following main characteristics of potential innovation ecosystems in infrastructure: (1) involvement of heterogeneous actors; (2) strategic alignment of actors; (3) alignment with respect to a value proposition; and (4) governance structure. By considering the structural elements of the infrastructure sector as discussed in the previous sections, these characteristics are detailed in several indicators as explained below, which together constitute the conceptual framework for qualitatively analysing five infrastructure initiatives.

6.4.1 Involvement of heterogeneous actors

Innovation ecosystems involve *cross-sectoral networks* rather than being limited to sectoral boundaries, a characteristic that is positively correlated with innovative solutions (Alves et al., 2007). This is largely because unfamiliar actors might bring expertise that cannot be found within the sector. In the infrastructure context, this could, for example, mean that chemical companies are involved in construction material innovations or IT companies in digital twin innovations. It is not only this heterogeneity that is typical of innovation ecosystems but also a reliance on *non-generic complementarities* (Jacobides et al., 2018). Actors provide these concerning the value proposition by offering unique skills or products that provide specific pieces of the puzzle needed to deliver the overall value proposition.

Collaboration in innovation ecosystems transcends the collection of conventional project participants, such as contractors, government agencies and engineering firms, and may include actors such as material suppliers, technological innovators, knowledge institutes, and civil society that cover the full *quadruple helix* (Carayannis et al., 2018). In addition to the industry, knowledge institutions and governmental bodies that are present in the triple helix model, a quadruple helix adds a fourth helix associated with “media and culture-based public”, allowing public society to become an integral part of innovation ecosystems (Carayannis and Campbell 2009, p. 206). Since the adoption of the innovation ecosystem perspective in an infrastructure context demands a wider view of the actors involved, we identify *cross-sectoral networks*, *non-generic complementarities,* and the *quadruple helix* as our three key indicators in analysing the actor heterogeneity of infrastructure initiatives.

6.4.2 Strategic alignment of actors

Combining the knowledge and expertise of various parties cannot only deliver a particular part of the solution, but inter-organizational collaboration can also result in solutions beyond the capacity of individual organizations (Ritala & Hurmelinna-Laukkanen, 2009). In the infrastructure sector, alignment can be found in the *coopetition* between individual market parties, the collaboration between contractor and client, and the involvement of actors throughout the entire infrastructure process rather than only in specific parts of the asset lifecycle.

Given that innovation ecosystems are dynamic networks rather than fixed structures, actors might only be involved for a limited period and with changing intensities and roles. This requires a perspective that goes beyond the traditional project structures and invites reconsideration of the traditionally oppositional client-contractor relationships (Ruijter et al., 2021). Consequently, actors might be *dynamically involved* throughout the construction processes to fully utilize their input and expertise, such as the involvement of demolition contractors in a pre-project stage to optimize products and processes over the asset’s entire lifespan (Van den Berg, 2019).

So, whereas suppliers in regular construction processes often become involved through a contractor, an innovation ecosystem perspective would allow the involvement of such knowledgeable parties directly and in earlier stages of the process. This requires distinct actors to align their work processes and to collaborate towards a central value proposition to collectively generate a desired outcome – a phenomenon known as *co-specialization* (Ritala et al., 2013). This strategic alignment has the potential to both find integral solutions and stimulate lifecycle thinking. We, therefore, identified *coopetition*, the *dynamic involvement of actors* and *co-specialization* as three indicators to be used in analysing the strategic alignment of actors involved in project-transcending infrastructure initiatives.

6.4.3 Alignment with respect to a value proposition

Aligning participants' incentives is key to facilitating the coordination of the various inputs required to go beyond project-specific solutions. In innovation ecosystems, this is achieved by creating conditions for developing a *shared value proposition* that is beneficial to all parties involved. Such value propositions could be operational or economic goals of, for example, cutting budgets, but could also relate to addressing wider public challenges, such as climate change or digitalization. While the infrastructure sector is known for distrust and poor communication (Van Oorschot et al., 2020), the innovation ecosystem perspective offers a system that fosters trust through goal alignment. The *alignment of incentives* therefore provides favourable conditions for collaboration and transparency (Fischer & Pascucci, 2017).

The alignment of incentives enables sets of actors to pursue goals that go beyond the success of a single project. Value propositions could therefore go beyond project performance in terms of time, budget and quality to outcomes related to overarching goals and missions, such as carbon reduction and social inclusion. This can be aligned at an industry level but might also be positioned at the level of an infrastructure client organization or a public-private consortium. Notwithstanding, its initiation must originate beyond the scope of a single project to align multiple actors beyond the temporalities of projects. This can contribute to solutions that projects or project portfolios can exploit wider throughout the sector and encourages parties to invest in innovation since the potential benefits extend over a longer term (Volker, 2018). Successful innovation ecosystems provide a *viable business case for all actors* involved. This will require radical changes in how construction activities are organized in terms of reward systems, risk allocation, contracting methods and, above all, the level of trust between parties. Based on these arguments, we will specifically look at the *shared value proposition*, the *alignment of incentives* and the *viability of the business case for all actors* to assess alignment concerning the value proposition of infrastructure initiatives.

6.4.4 Governance structure

Innovation ecosystems are primarily non-contractual in nature, with autonomously acting participants, characterized by interdependence through co-specialization. The shared value proposition ensures that all participants can find their position within the innovation ecosystem with *low levels of formality* and a strong reliance on relational governance (Colombelli et al., 2019). This enables participants to take flexible roles throughout the process through governance in a *co-alignment structure* that goes beyond formal contracts (Thomas & Autio, 2019). Accordingly, the governance mode may vary from top-down and hierarchical to informal coordination. Infrastructure projects are usually highly formalized and procurement legislation generally impedes the formation of long-term collaborations and project clusters.

The innovation ecosystem perspective, however, demands ways to increase autonomy and flexibility within projects and entails forms of *self-organization*. This stimulates the exploitation of expertise (Poirier et al., 2016). It therefore provides the conditions for actor heterogeneity, which requires fundamental changes to how infrastructure projects are currently governed. Also, the self-organizing potential is affected by whether or not a central actor orchestrates processes and actors within the network (Phillips & Ritala, 2019). Given its large stake in addressing long-term and societal challenges, the orchestrator in the infrastructure sector is often a public actor that, although bound by procurement regulation, constructs stakeholder networks with the aim of adding value to society (Eriksson et al., 2019; Fuentes et al., 2019). On the other hand, such an orchestrator could also come from the private sector, where a private organization actively connects and aligns the actions of different parties aiming to develop a particular innovation. However, the road towards broad implementation of this innovation is more uncertain within current sectoral structures due to the limited possibilities of public organizations to apply unsolicited proposals (Chapter 2). Hence, in this study, the governance structure will be assessed based on *low levels of formality*, *co-alignment structure* and *self-organising potential*.

6.5 Research approach

Given that the innovation ecosystem perspective has proven to be valuable in various fields in stimulating change and innovation concerning wider societal challenges (Jütting, 2020), we will explore its applicability in a particular segment of the Dutch construction industry that focuses on the development and maintenance of physical infrastructure such as bridges, roads and waterways. We analysed five existing exemplary public infrastructure cases by applying the conceptual framework on innovation ecosystem characteristics – actor heterogeneity, strategic alignment of actors, alignment with respect to a value proposition and governance structure – and associated indicators as described in the previous section.

6.5.1 Case selection and description

For this study, we used a purposive sampling strategy for selecting cases (Campbell et al., 2020). The selection was based on the identification of noteworthy infrastructure initiatives in terms of project-transcending collaboration and value creation related to societal challenges such as circularity and sustainability. In all cases, either a client, public-private network or contractor initiated a value proposition in line with long-term challenges that could not be resolved within one or several single projects. To this end, we consulted experts in the Netherlands (e.g., fellow researchers in the infrastructure sector and managers with a broad network) and compiled a list of ten potential cases that facilitate a broader exploration of the innovation ecosystem potential. Next, we collected more information on these cases through publicly available documents to identify whether two or more of our four innovation ecosystem characteristics (actor heterogeneity, strategic alignment of actors, alignment with respect to a value proposition and governance structures) were at least to some extent present. We used information we found online, such as news articles, web pages, and YouTube videos, as well as documentation sent to us by the experts we consulted, such as tender documentation.

Next to the presence of innovation ecosystem characteristics, the ten potential cases were evaluated on three aspects: (1) organizations linked to the initiative are involved on a long-term basis; (2) the goal of the initiative includes a central value proposition that is impossible to accomplish within a single project; and (3) the central value proposition is related to societal challenges. We particularly looked for typical or striking elements that made the initiative unusual for the Dutch infrastructure sector, such as the number of parties from outside the construction industry and the underlying business models or contracts. This approach enabled us to either confirm or refute inferences drawn from individual cases (Eisenhardt & Graebner, 2007) and resulted in a set of five cases.

The five selected cases are as follows: an innovative long-term and trust-based collaboration using long term framework agreements with three contractors to ensure wastewater treatment from the Dutch Waterboard of Limburg (*Case 1 Water Treatment*); the CHAPLIN consortium which aimed to explore and introduce lignin as a substitute for bitumen in asphalt, where, among others, infrastructure and paper industry parties closely collaborated (*Case 2 Bio-pavement*); the “Circulaire Weg” programme that introduced a service-based business model to be tested in several road-contracting pilot projects to contribute to the CE (*Case 3 Circular Road*); the “Cirkelstad” knowledge platform which aimed to connect and align all willing actors in the

Table 15. Major elements of the five cases studied.

	Case 1 Water Treatment	*Case 2 Bio-pavement*	*Case 3 Circular Road*	*Case 4 Circular City*	*Case 5 Asphalt Innovation*
Domain of interest	Construction and maintenance of wastewater treatment plants	Development and commerciali-zation of lignin-based asphalt	Exploring the infra-as-a-service business model in pavements	Connecting actors that aim for circularity in the built environment	Knowledge building on asphalt in line with societal challenges
Initiator	Waterboard of Limburg (WBL) (public client in infrastructure)	Circular Biobased Delta Foundation (a shared initiative of public and private parties)	Dura Vermeer (contractor)	Foundation Cirkelstad (a shared initiative of public and private parties)	Rijkswaterstaat (public client in infrastructure)
Collaborative structure	Formal framework agreement including three contractors per domain	The foundation acts as a platform for the participating organizations	Informally arranged collaboration, followed by formal pilot projects	Foundation acts as a platform and facilitates and ties the participating organizations	Formal covenant with participants: working groups act on an informal basis
Parties involved	Client, three contractors, suppliers, independent process coach and others	Twenty-eight organizations, including public bodies, knowledge institutes and cross-sectoral market parties	One contractor, one knowledge institute, one consultancy firm, independent programme manager, two banks and six public clients	Multitude of actors across multiple regions including public clients, knowledge institutes and market parties	Broad range of infrastructure organizations, including public clients, knowledge institutes and market parties
Time-frame	Flexible with maximum of six years	Indeterminate	Two years (with long-term as-a-service contracts)	Indeterminate	Five years

built environment to provide conditions for the implementation of circular and inclusive cities (*Case 4 Circular City*); and the “Asfalt Impuls” programme, involving a multitude of different organizations who aim to further knowledge on sustainable asphalt in order to achieve the sector’s sustainability goals (*Case*

5 Asphalt Innovation). Table 15 gives an overview of the domains of interest, initiators, collaborative structures, parties involved and time horizons for each case.

6.5.2 Data collection and analysis

After the initial analysis to select suitable cases, additional data on the five cases were collected using documents from professional magazines, newspapers, websites, and other journals. This resulted in a data set containing fifty-two data sources consisting of written documents and videos. As a first step in analysing the cases, we structured the data per case and used the case datasets to summarize the different cases in terms of the governance structure, the constellation of participants in the initiative, the aim of the initiative and the way in which participants collaborated. The different data types provided different 'parts of the puzzle' in developing the case descriptions, going iteratively back and forth through the obtained information (Eisenhardt, 1989). There was an average number of about ten data sources per case, which made the dataset per case comprehensible and manageable. Therefore, the analysis of the data for each distinct case was conducted manually. This first step resulted in five general case descriptions and helped the researchers gain a deeper understanding of the different cases.

As a second step, the four innovation ecosystem characteristics were used to enhance the five case descriptions with specific information regarding innovation ecosystem indicators for each characteristic. Again, the researchers followed an iterative approach to make sense of the data. Through cross-case comparison (Eisenhardt, 1989), different elements were identified about the characteristics' underlying indicators, such as the level of formality and coopetition. The innovation ecosystem characteristics and indicators were used in a qualitative manner to distinguish between the different cases. For example, the *heterogeneity* characteristic was further specified by distinguishing between distinct types of sectors, types of actors and types of inputs. When, in this example, actors from sectors other than infrastructure were involved in the initiative, this was understood as a form of heterogeneity. As a second example, when the initiative depended strongly on actors that offered specific and unique types of products, knowledge, or services with respect to delivering the overall value proposition, we described how the initiative includes *non-generic complementarities*. In cases where the information collected was inadequate, we searched for additional documentation specifically on the aspects that remained unclear and reached out to involved actors of the initiatives to verify our data, leading to complementary informal interviews with several of the project managers and board members of the cases.

Based on the validated descriptions of the cases and descriptions of the indicators per case, it became clear how each case dealt with collaboration and innovation in a project-transcending setting. Based on these elaborate accounts of the cases, a comparison between the five cases was conducted. Remarkable elements and achievements of the cases were put side-by-side and were related to the elements as described in the conceptual framework. This enabled us to reveal the potential opportunities, benefits, and challenges in applying the innovation ecosystem perspective on an industry-wide level. These outcomes are presented in the next section.

6.6 Results

Table 16 provides an overview of the four main innovation ecosystem characteristics and their indicators on the vertical axis, and a summary of the related elements found in the five cases on the horizontal axis. Matches between cases and indicators are indicated in **bold**. These matches are determined based on a qualitative assessment of the cases based on the data sources, which are individually described in the next sections. For instance, regarding cross-sectoral networks, in Case 1, we could only find actors that are generally affiliated with the wastewater industry, while, in Case 2, parties were found from the asphalt sector and the lignin industry. The latter was hence indicated in bold. Table 16 shows that some indicators were found in all cases, while others were only present in one or two cases. The results are discussed in greater depth in the next sections according to the four innovation ecosystem characteristics.

6.6.1 Actor heterogeneity

In all five cases, various actors from the supply chain were involved, but in only one case did actors from outside the infrastructure sector play a role. This was in *Case 2 Bio-pavement,* which actively sought to combine knowledge on asphalt paving with the chemical and paper production industries, where lignin is a residual product released during the production of, among other things, pulp and cellulose. This case demonstrated that by actively reaching out beyond sectoral boundaries, solutions were found that opened up a solution pathway that could potentially transform the asphalt subsector. Deliberate collaboration across the value chain was organized by the orchestrating foundation to create a network of actors in bio-pavement rather than a linear supply chain. The network of the bio-pavement case consisted of ten market organizations, nine public organizations and five research institutes. Furthermore, the network crossed several regions, sectors and domains aiming to achieve a system of

Table 16. Innovation ecosystem characteristics and indicators for the five cases studied.

	Actor heterogeneity			*Strategic alignment of actors*		
	Cross-sectoral networks	*Non-generic complemen-tarities*	*Quadruple helix*	*Coopetition*	*Dynamic involvement of actors*	*Co-specialization*
Case 5 Asphalt innovation	Infrastructure actors only	Actors with specific knowledge	Representation of triple helix, no active involvement of society	Knowledge sharing, but limited overall coopetition	Occasional involvement of participants, but fixed in working groups	**Co-creation and co-specialization on distinct levels; sector-wide application of deliverables**
Case 4 Circular city	Infrastructure actors and potentially connecting other sectors	Generic complemen-tarities	Representation of triple helix, no active involvement of society	Knowledge sharing, but limited overall coopetition	**Dynamic involvement of participants**	Mostly aimed at connecting co-specialized actors
Case 3 Circular Road	Infrastructure actors only, but acting in non-conventional roles	Generic complemen-tarities	Representation of triple helix, no active involvement of society	No coopetition	Dynamic involvement of public clients (in pilot projects)	**Utilizing all participants' specialisms in integrated development cycles**
Case 2 Bio-pavement	**Actors from other industries involved**	**Specific actors with non-generic complemen-tarities**	Representation of triple helix, no active involvement of society	**Coopetition between contractors and suppliers**	**Continuous and dynamic involvement of relevant parties**	**Utilizing all participants' specialisms in integrated development cycles**
Case 1 Water treatment	Infrastructure actors only	**Specific module suppliers**	Representation of triple helix, no active involvement of society	**Coopetition between contractors**	**Continuous and dynamic involvement of relevant parties**	**Parallel and partly co-specialized development cycles for modular parts**

	Alignment with respect to a value proposition			*Governance structure*		
	Shared value proposition	*Alignment of incentives*	*Viable business case for all actors*	*Low levels of formality*	*Co-alignment structure*	*Self-organizing potential*
Case 5 Asphalt innovation	**Quality improvement of asphalt**	**Alignment by shared rewards from being frontrunners**	Potential future competitive advantage for participants	Formalized governance structure based on voluntariness of participants	**Governance allows participants to take on dynamic roles beyond**	Orchestrated by government organization
Case 4 Circular city	**Creating and sharing knowledge on circularity**	**Alignment by both adding and using knowledge from central platform**	Potential future competitive advantage by novel network relations	**Formal foundation, but relationships strongly non-contractual**	**Governance allows participants to take on dynamic roles beyond formal contacts**	**Self-organizing but orchestrated by board**
Case 3 Circular Road	**New business model in infrastructure (as-a-service)**	**Alignment by belief for necessity of novel contract forms**	**Present**	Formal dyadic contracts in a closed network	Inflexible governance structure	Initiated by contractor, yet collaboratively steered
Case 2 Bio-pavement	**Bio-based asphalt innovation**	**Alignment by perspective on pilots and future work**	**Future competitive advantage for participants**	**Informal, non-contractual relations in voluntary consortium**	**Informal governance structure allows external actors to participate**	**Self-organizing but orchestrated by a central foundation**
Case 1 Water treatment	**'Good' wastewater treatment plants and a smooth work process**	**Alignment by fair and long-term sharing of risks and benefits**	**Strongly present**	Formal framework contracts, but low formality within the framework	**Flexible governance structure to fit programme goals**	Initiated and managed by Waterboard

*Strongly matching traits are indicated in **bold**.

industrial symbiosis. Although the other four cases did not go beyond the sector's boundaries in terms of the actors involved, their organization of the supply chain and adoption of a network perspective resulted in long-term actor involvement throughout all construction phases. This enabled a more effective exploitation of all the actors' knowledge and skills.

Not involving actors from outside the infrastructure sector and providing the conditions necessary to go beyond the sectoral boundaries contrasts with typical innovation ecosystems that involve actors that offer non-generic complementarities to the value proposition. Nevertheless, in *Case 1 Water Treatment,* non-generic module suppliers were added to assemble their innovative modular wastewater treatment plant. This arrangement used framework agreements to purchase specific solutions from specific suppliers and avoid project-oriented procurement restrictions. This enabled the client to compile a catalogue with solutions aimed at standardizing specific wastewater treatment plant technologies and achieving a standardized and integrally sustainable system design.

In all five cases, actors outside the conventional supply chain, such as knowledge institutes, were involved next to the usual actors as governments and marked organizations, resulting in a representation of the triple helix. The main reason to involve knowledge institutes seemed to be the frontrunner role of the initiatives, which encouraged reflexive activities related to experimenting, learning, and reflecting. The fourth helix of civil society was not involved in any of the initiatives. Since the customer is in most infrastructure assets not an individual consumer but a governmental client that represents societal interests, the absence of the fourth helix does not seem to be problematic for the ecosystem development in these particular cases. However, the deliberate inclusion of this fourth helix might still be valuable in cases where the value proposition directly affects citizens, such as urban infrastructure works.

To summarize, we found that the actor heterogeneity was in most of the cases rather similar to those in conventional project settings, with only the Case 2 *Bio-pavement* showcasing the potential benefits of crossing sectoral boundaries. The need for extensive actor heterogeneity seems strongly connected to a value proposition that goes beyond what conventional infrastructure actors can achieve.

6.6.2 Strategic alignment of actors

The deliberate alignment of actors in terms of mutual dependencies and project-transcending collaboration was found in all five cases, although not all to the same extent. Particularly in the product-oriented cases (Cases 1 and 2), actors were aligned in line with innovation ecosystem principles in such a way that coopetition between parties played a key role. Nevertheless, contractors still had to compete in tenders for projects outside the scope of the studied networks, such as infrastructure projects commissioned by other public clients.

The results from *Case 1 Water Treatment* indicate that involving several contractors in one multiyear framework agreement stimulated coopetition between the contractors involved. In this case, the three contractors were primarily selected for their collaboration competencies rather than for traditional criteria such as lowest price or price/quality ratio. As part of the contract, the risks and profits involved were shared fairly among the client and the contractors. The resulting collaborative attitude of all parties resulted in a considerable reduction of cost and time overruns, as well as an increased number of unconventional solutions. It also promoted cross-project learning, standardization, and alignment of incentives between all actors, and enabled investments for innovation. An external process coach was involved in discouraging any tendencies by parties to adopt traditional opportunistic behaviour rather than collaborative attitudes. Her job was to independently safeguard the collaborative relationships and to resolve potential tensions through constructive dialogue.

Case 4 Circular City and *Case 5 Asphalt Innovation* were primarily knowledge-oriented and showcased limited collaboration, which resulted in limited or no competition: knowledge was shared among participating organizations, but participants did not collaboratively exploit this knowledge to provide novel solutions. Within these networks, there was no direct relation to immediate profits or work, which likely explains the absence of competition between the participants. Hence, in the knowledge-oriented cases, overall coopetition was limited. These cases did not pose any procurement challenges, leading to relatively open system collaboration structures and the involvement of various actors and actor types. In *Case 4*, the actors were primarily aligned on a regional level, in which individuals orchestrated this alignment. Wider outcomes in terms of knowledge or lessons were directed towards the national level and shared within the wider initiative. As such, there was little interdependence and the actor heterogeneity largely depended on mere coincidence. In *Case 5*, all the members were able to contribute to the programme and could propose projects in line with the initiative’s value proposition. A central steering group decided which of the proposed projects would be initiated as thematic working groups. As such, there was little room for deliberate upfront actor alignment.

In *Case 1 Water Treatment* and *Case 2 Bio-pavement,* the actors were strategically aligned to create a clear flow from development, through testing, to implementation. The *Bio-pavement* case in particular showed a remarkably high actor interdependence concerning the goal. This resulted, on the one hand, in a high level of collaboration between the contractors and, on the other, in forms of co-specialization. As such, sustainable innovations that would have been difficult to introduce in single-project and single-industry environments were successfully introduced in pilot environments. Key to these cases was the project-transcending collaboration between clients and market parties and between the market parties themselves. This was mainly achieved by reconsidering the traditional actor alignment structures and adopting a long-term output orientation rather than a project focus.

Overall, the current infrastructure sector does not seem to provide the tools needed to strategically align actors in line with innovation ecosystem principles. In the two product-oriented cases (Case 1 and Case 2) this was solved by non-conventional and project-transcending forms of collaboration. These project-transcending collaborations seem to be essential to facilitate the coopetition and co-specialization necessary to address long-term objectives.

6.6.3 Alignment with respect to the value proposition

We only selected cases aiming at value propositions that addressed goals beyond single projects. We found that rather than being an objective of a client organization only, these value propositions were shared and supported by all the actors involved through the alignment of incentives. In *Case 1 Water Treatment*, however, the value proposition was not that different from conventional construction projects. Nevertheless, in combination with the contextual conditions that were set by the client – in particular incorporating principles for hassle-free collaboration and a fair distribution of project risks, gains, and losses – the actors involved committed to collaboration and to accomplishing the project and programme goals. The value propositions were, however, not accurately stipulated and appeared to range from standardization to increasing sustainability. This created flexibility throughout the contracted period and the dynamic incorporation of long-term value-based objectives.

We found that all the cases employed numerous ways to align the incentives with the value propositions. Four of the five cases had sustainability-oriented value propositions that were aligned with the contributions of the actors. In *Case 4 Circular City*, for instance, actors were connected through a platform in which collecting, sharing, and diffusing knowledge was aimed at improving sector-wide knowledge on circularity and inclusivity in the built environment. The value proposition of *Case 3 Circular Road* involved as-a-service road contracts that aligned the actors around specific long-term contracts that emphasized circularity principles in the integration of construction, maintenance, and demolition. Novel forms of contracting, relation-building and collaboration were found to be essential for aligning the incentives of the actors and activities to a central value proposition and the case data showed several effective examples of such alignment strategies. In addition, in all cases, the actors participated of their own accord and hence signed up to align with the central value proposition beforehand.

Overall, in all the cases, participating in the network or initiative seemed to be a promising move when considering the viability of the business case for each participant. Although the participants could not always expect to profit directly, the advantages of participating in a broader network initiative, such as expanding business relations, access to knowledge and possibilities to innovate with less risk, delivered potential future value for other projects.

6.6.4 Governance structure

The low level of formality that typically characterizes innovation ecosystems could only be identified in two cases: in *Case 2 Bio-pavement* a consortium was established and in *Case 4 Circular City* the governance was purely relational around a central platform. However, product-oriented *Case 1 Water Treatment* and *Case 3 Circular Road* demonstrated several ways to increase collaboration with low levels of formality within the more formal boundaries of public procurement. Case 1 achieved a low level of formality by procuring collaboration for several years instead of project delivery within a strict performance frame, while Case 3 shifted from purchasing a product towards purchasing a multi-year service delivery. This resulted in cross-project collaboration and tighter client-contractor relationships in which relational governance mechanisms overshadowed the initial, contractual governance as the collaboration proceeded. The relational governance mechanisms offered more possibilities to make better use of the participants' strengths throughout the process. Overall, apart from Case 4, the final outputs were nevertheless eventually formally stated in contracts.

In four out of five cases, the regular procurement practices were either omitted or adjusted to establish relationships with less formality and to stimulate the collaboration needed to achieve cross-project challenges. As such, an overall shift was made from contractual governance mechanisms towards relational governance mechanisms. This allowed for a better alignment between actors with respect to the envisioned value proposition based on their skills and knowledge to contribute to it.

All the cases extended the scope beyond single projects, emphasizing the need for durable relationships and resulting in higher degrees of mutual trust compared to typical stand-alone infrastructure projects. For example, although the encompassing framework agreement in Case 1 was formally procured, we found that the collaboration within the framework agreement was largely horizontal and informal.

In *Cases 2 and 4*, the networks were self-organizing and/or informally governed, based on rather informal networks. In Case 2, the network was always open to new members, and the only condition for participating in the network was that members must add something to the collaboration and value proposition. This non-formal structure led to a diverse range of parties becoming involved, all with specific strengths and complementarities that contributed to the central goal: bio-based asphalt development.

To summarize, in most cases the nature of the work and legal boundaries did not seem to allow for a high degree of non-formal governance. Nevertheless, in all the cases actors did find ways to shift the governance from contractual towards relational. The lower levels of formality contributed significantly to a more open and dynamic attitude towards solutions that went beyond the project scope.

6.7 Benefits of taking an innovation ecosystem perspective

Each case indicated different benefits and challenges by taking the innovation ecosystem perspective on innovative value propositions and project-transcending collaboration. These are discussed below for each case.

In *Case 1* the procurement of multi-year framework agreements with multiple contractors provided the conditions required for aligning objectives towards a shared project-transcending goal that includes a novel modular wastewater treatment plant in line with the water board's wider CE ambitions. This was primarily achieved by sharing risks and benefits fairly, and by managing the underlying projects through collaboration on a cross-project perspective for four years. In addition to the benefits of stimulating innovation, these agreements also led to conditions that allowed for project-transcending standardization efforts. Reflected by the presence of non-generic complementarities, strong coopetition and deliberately aligned incentives, the conditions were created for addressing challenges beyond a project's scope and deliberately innovating to meet these challenges.

Rather than employing novel ways of collaboration to provide conditions for innovation and change, *Case 2* was initiated around a clear innovation purpose: to address the transition towards carbon-neutral infrastructure through bio-based alternatives. The way of organizing – cross-sectoral networks, a high degree of coopetition, dynamic partner involvement, and specified participant roles – was a consequence of this objective rather than an act to trigger innovation. Nevertheless, the close similarities with the innovation ecosystem characteristics led to an effective innovation pathway that covered all the phases from idea development, through experimentation, to implementation beyond single project settings. This approach turned out to be highly effective for exploring and implementing bio-based substitutes for bitumen in asphalt and was later on linked to a larger cross-sectoral programme aimed at addressing overarching objectives concerning sustainability and the CE.

In a similar vein, *Case 3* was initiated around a particular business model innovation to respond to a wider societal challenge: the CE. Contributing to this societal challenge was the main reason for public clients to join the market-driven initiative. Despite having only limited similarities with the innovation ecosystem characteristics, the extension of the project scope beyond the conventional design and construction phases enabled the actors to align the incentives towards making infrastructure decisions that were more resource-efficient. The value proposition was centred around the promising presumption that having integrated lifecycle stages as the responsibility of contracting actors would lead to more resource-efficient behaviour, and hence wider economic and environmental benefits in the long run.

In contrast to the above three cases, *Case 4* did not focus on cross-project activities but on transforming the wider built environment sector. As such, this network-level approach did not directly contribute to specific innovations, but mainly to knowledge diffusion and collaboration to accelerate a market transformation towards circular practices. In particular, the relational governance structure enabled participants to take on dynamic roles in the network towards meeting the value proposition in context-specific and case-specific settings.

Although *Case 5* had more concrete objectives than Case 4, it was also aimed at wider sectoral improvements. The long-term policy objectives were strongly interrelated with innovation and with change objectives such as closer collaboration among client organizations, market parties and research institutes. By utilizing thematic working groups, directions towards concrete solutions were explored and developed in a highly heterogeneous and cross-project setting. The case platform represented almost the entire Dutch asphalt supply chain and created opportunities for wider standardization in line with policy objectives. This largely government-led initiative thus contributed directly to the societal challenge-oriented strategic missions of the Dutch government.

Despite the different objectives and organizational structures, in all the cases the potential for change was increased by stepping out of the conventional project setting. A consistent governance system in which their value proposition was shared among a broader set of actors or time horizons seemed to have created opportunities for pursuing innovation in line with project-transcending societal challenges. As such, the results indicate that working in line with innovation ecosystem principles seems both feasible and beneficial with respect to achieving value propositions beyond the project scope. Nevertheless, it is important to note that all cases fundamentally differ in structure and context.

There is probably no ideal innovation ecosystem model, formula or archetype for achieving project-transcending innovation. Based on this exploration we can carefully speculate if stronger implementation of innovation ecosystem principles could have increased the effectiveness of achieving the value propositions as set by the actors in these specific cases. In *Case 2*, for example, other industries contributed to innovative solutions with different technologies and knowledge. Extending the heterogeneity of the partners might hence have widened the solution space and consequently the value creation in this case. Similarly, more room for self-organization and emergence is likely to have contributed to the origin of non-conventional solutions and eventually wider sector support to achieve the value proposition regarding asphalt innovation in *Case 5*.

6.8 Reflection and discussion

While scholars such as Davies *et al.* (2014) and Whyte *et al.* (2016) introduced the ecosystem perspective in a project environment, we explored its potential for facilitating value propositions from a project-transcending angle. In line with Ferraro *et al.* (2015), our analysis of the five cases from the Dutch infrastructure context confirms that the presence of innovation ecosystem principles allows for actor relationships to develop and provides conditions to foster long-term engagement towards a shared goal. Moreover, this perspective provides a continuous and value-based economic view beyond conventional single object-oriented project settings and occasional coalitions (Halman, 2018). As such, the innovation ecosystem perspective allows the value proposition to exceed the project scope, which is considered crucial for addressing societal challenges (Ingold et al., 2019).

In line with Pulkka *et al.* (2016), we identified a potential benefit of adopting an innovation ecosystem perspective to innovation and change in the construction industry. Whereas Pulkka *et al.* (2016) placed a network view centrally to increase value creation in a network context, we positioned project-transcending value propositions as focal points. This is an essential step for the construction industry to address societal challenges, because seeking to achieve societal missions, such as climate neutrality and CE, requires solutions that go beyond detached industries or single supply chains. Actors need to align incentives beyond conventional project settings and create a long-term commitment to shared objectives (Jütting, 2020). The innovation ecosystem perspective could hence play a significant role in achieving societal challenges on a sectoral level, for example, by providing specific insights on initiating or changing institutions that currently appear to hinder innovation and change.

Our analysis revealed that longer-term and less contractual cross-sectoral relationships can result in solutions that go (far) beyond the scope of conventional project-based public-private infrastructure supply chains in the infrastructure context. Many of the innovations and solutions in the studied cases essentially trace back to the informal relationships between actors. This is in line with previous work on collaboration in construction (e.g. Hällström et al., 2021). We found that innovative solutions with a significant impact regarding the project-transcending value propositions were largely the result of relational and longstanding actor interactions.

Previous work distinguishes between two layers in innovation ecosystems (Visscher et al., 2021): the explorative layer focuses on developing knowledge and opportunities for innovation, and the exploitative layer focuses on executing work efficiently and effectively. The results of our study indicate that whereas the latter can be achieved within the existing project-based structures, the former requires fundamental changes to practices and the adoption of a project-transcending perspective. So, for the innovation ecosystem perspective to be effective in delivering long-term value propositions in public project-based sectors like infrastructure, one should step away from relying on the requirements within or between single projects. Since exploration precedes exploitation, a well-functioning explorative layer may lead to an exploitative layer of projects with different kinds of partners and value propositions (Visscher et al., 2021).

Our study revealed novel approaches to the explorative layer in the form of pilots or field labs that fit the early phases of systemic transitions (Rotmans & Loorbach, 2009). However, upscaling solutions from pilot environments to regular practice remains challenging. Balancing between collectives of actors that explore new solutions, those that exploit these solutions, and those that both explore and exploit, could be instrumental in addressing the challenges on a systemic level (Van den Buuse et al., 2021; Visscher et al., 2021).

Finally, one should be aware that an innovation ecosystem perspective requires fundamental changes in terms of inter-organizational governance. Such systemic reconfigurations take time and perseverance and would, next to novel technologies and approaches, require a cultural and processual shift throughout the sector (Grin et al., 2010). The construction sector would have to change its culture from relying on formal contractual arrangements based on established roles and routines to trust-based social ties in long-term collaborative relationships (Hällström et al., 2021; Hedborg & Karrbom Gustavsson, 2020). Hopefully, our results offer a starting point for shaping this challenging journey.

6.9 Conclusion

Given the temporal complexities of project settings, it remains challenging to increase the collaborative action needed to provide the conditions for change and innovation in the construction industry. We aimed to contribute to this challenge by addressing the long-standing call by Bygballe and Ingemansson (2011, p.169) to establish ways to "see the benefits of interacting over time and attempt collaboration across projects" in the infrastructure domain. This was done by adopting the innovation ecosystem perspective and by structurally applying it to construction. We showed how it can offer a different understanding of change and innovation compared to the dominantly project-based structure and relatively homogeneous sector perspectives.

Collaboration following the principles of an innovation ecosystem can add value by shaping the consortia of actors towards wider societally oriented value propositions that produce innovations beyond the benefits of single projects. This includes not only the alignment of actors with respect to the overall value proposition but also the deliberate alignment of actors' activities to achieve such aspirations. Our research shows that using framework agreements and programmatic collaborations are promising directions in enabling long-term and diverse collaborative initiatives that have the potential to grow into practices that fit the innovation ecosystems perspective. As such, the innovation ecosystem perspective provides a promising starting point for understanding and establishing the conditions required to deal with the major societal and sectoral challenges.

Utilizing this potential would require taking full advantage of the competencies of a more heterogeneous set of individual actors, while also keeping eyes peeled for actors outside the conventional value chain and the sectoral boundaries. Since the existing institutional settings of our sector do not easily accommodate this, substantial changes will be required in conventional role structures and work practices. This collaborative transformation needs substantial effort in terms of experimentation, evaluation, and learning. Key factors are value-based contracting, partnering, procurement, risk, and profit allocation, and facilitating trust-based relationships. Working in ecosystems will also substantially impact the economic systems and business models in which infrastructure actors operate. Inevitably, these transition processes will continue to increase the complexity of the construction industry as a system.

6.9.1 Limitations and further research

Given the potential benefits of wider adoption of the innovation ecosystems perspective in construction, we strongly argue for further research into its potential applications and specific theory development for project-based environments. Although our study was confined to the infrastructure context, we also expect the potential of an innovation ecosystem perspective to be beneficial to the wider construction sector. For example, commercial real estate and office developments are less restricted by public procurement law, which may increase the space for long-term collaboration and allow for higher degrees of relational governance than infrastructure. Building construction projects usually also have a diverse set of public and private stakeholders involved which could change the degree and types of complexity regarding alignment of incentives towards a shared value proposition. Finally, the fact that real estate assets are not part of a network, which holds for infrastructure, could also affect the type of value propositions. This requires further research.

We put relatively little emphasis on how the various cases emerged or why they organized themselves as they did. In addition, the conceptual lens does not provide ingredients for developing or managing innovation ecosystems. Further research could deepen this exploration, for example by studying cases that embody several innovation ecosystem characteristics in greater depth, in a more quantitative way or over time, to create a longitudinal view of the evolution of innovation ecosystems in line with Brunet *et al.* (2021). This would also enable studying the different development trajectories from a multilevel view on organizing as applied by Sydow and Braun (2018), providing further insights into the institutionalization of necessary conditions for innovation ecosystems to emerge.

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chapter 7

conclusions and outlook

This dissertation aims to generate the insights needed to further the transition towards a circular infrastructure and addresses the question of *how the mission-oriented transition towards circular infrastructure can be governed*. Through the work presented in the previous chapters, I showed ways to anticipate and steer socio-technical change towards a circular infrastructure sector. In this chapter, I will address each research question separately and reflect on the main research question. A reflection on the overall contributions to practice and theory follows the general conclusions. Finally, I provide an outlook on future research.

7.1 Concluding the research questions

RQ 1 *What are the systemic barriers and lock-ins to transitioning towards a circular infrastructure sector?*

Three vicious cycles were identified that hamper a transition towards a circular infrastructure sector using the Mission-oriented Innovation System (MIS) analysis: (1) the *circularity contestation cycle*; (2) the *knowledge diffusion cycle*; and (3) the *innovation cycle*. These cycles are self-reinforcing and, therefore, result in a non-circular equilibrium that must be breached for the sector to become inherently circular.

The *circularity contestation cycle* in Dutch infrastructure involves a divergent understanding of problem-solution dynamics around the circularity context, complicating the development and upscaling of circular solutions. This contestation, coupled with the sectoral characteristics, such as long lead-times, hampers reflexive monitoring and long-term funding. Considering the high entanglement with politics, the contestation further hampers the prevalence of circular solutions for long-term goals. This results in the slow implementation of circular solutions within organizational processes, which, in turn, sustains the divergent understanding of circularity through the fragmentation of circular initiatives.

The contestation of the circularity concept and its low priority also affects the *knowledge diffusion cycle*. Limited circularity knowledge and capacity hinder learning and the practical application of the circularity concept, making it challenging to implement and diffuse circular knowledge in organizations. The slow implementation of circularity knowledge leads to a failing resource and capacity allocation. This deficiency is reinforced by the low priority given to circularity compared to traditional infrastructure values like risk mitigation and traffic continuity. As a result, circular solutions barely escape the pilot project stage. The limited implementation and diffusion of circularity knowledge leads to a lack of a knowledge infrastructure for circular practices. This results in poor knowledge availability for non-experts and, in turn, a slow implementation of circularity in organizations.

The vicious and transition-hampering *innovation cycle* is mainly caused by prescriptive procurement methods and a risk-averse sector culture, hindering the introduction of novel circular alternatives. A lack of a long-term direction caused by the contestation of the circularity concept impedes further innovations crucial for the circularity transition. This lack limits the uptake of circular market-led innovations. Infrastructure clients prioritize stimulating market solutions on a pilot scale rather than more fundamental (i.e., systemic) socio-technical changes, maintaining the prescriptive nature of infrastructure procurement and impede more radical innovations for circularity.

Addressing single issues and introducing isolated innovations is insufficient to accelerate the transition towards a circular sector due to the multidimensional nature of these causalities in the broader system. Approaches to disrupt the vicious cycles must consider the system’s interdependencies, emphasizing the importance of addressing barriers at the sectoral level. Here, the contestation of the circularity concept stands out as a root cause that ties into all three cycles. See Chapter 2 for more details on these findings.

RQ 2 *How is circularity in the Dutch infrastructure domain perceived by infrastructure stakeholders, and how do the various perceptions align with the formal circularity mission?*

As appears from addressing RQ 1, contestation of the circularity concept is a root barrier to the transition. However, it is crucial to fathom the various perceptions of the transition’s direction to further it. After all, misalignment creates the risk of inducing inaction, inefficiency, and even undesired circularity outcomes. These perceptions are conceptualized as coherent constellations of problems circularity aims to address and solutions to address those – i.e., socio-technical imaginaries. Results indicated that circularity is perceived in three ways, each representing a separate socio-technical imaginary by Dutch infrastructure practitioners. We named these imaginaries: (1) *We need to use fewer resources more efficiently* (in short, *Resource efficiency*); (2) *Let’s reimagine design strategies* (in short*, Design strategies*); and (3) *Construction needs a mix of solutions* (in short *Mixed solutions*).

The *Resource efficiency* imaginary is represented by practitioners who see circularity predominantly as a set of principles to reduce primary resources. This imaginary primarily aims to avoid resource depletion and promotes a climate-neutral society at large through resource-efficiency. While generally addressing the same underlying challenges, the *Design strategies* imaginary emphasizes the need for waste reduction and prioritizes innovative design strategies to become circular. Finally, the *Mixed solutions* imaginary has a much stronger focus on the materials' side of circularity. Rather than focusing on mere design solutions, it considers the broader set of solutions, determining the conditions for circular infrastructure, such as material passports, procurement approaches, digital innovations, and monitoring systems. As such, it aims at offering the conditions to work circular rather than the circular outcomes themselves.

Strikingly, none of these imaginaries fully aligned with the central government's formal circularity strategy in the Netherlands. First, the formal strategy largely neglects the solution strategies, particularly in terms of design measures. Second, the formal strategy directs firmly towards the need for regulation and standardization, while practitioners hardly prioritize this. Third, the formal strategy took a broader view on the challenges to which circularity could offer solutions, including a more extensive set of environmental and societal impacts (e.g., biodiversity loss and social equity). To address this, either or both the sectoral perceptions should be converged towards the government's strategy and the strategy should be aligned with the sectoral perceptions.

Two approaches that allow policymakers to deal with this apparent contestation can be distinguished, both among practitioners and between practitioners and the formal strategy. First, *constructive approaches* offer a space in which the various perspectives are introduced in stakeholder dialogues and interactions to inform decision-makers on adjusting or renewing existing strategies, of which this Q-methodology approach is an example. Crucial in those *constructive approaches* is the aim to converge the understanding of the contested topic at hand. On the contrary, *agonistic governance* approaches become relevant when consensus is unlikely to be achieved. The *agonistic approach* thus allows for the coexistence of the plurality of views to prevent standstills by taking decisions on epistemological grounds while acknowledging and, if possible, internalizing other views without striving for consensus. Given the strong disagreements and the calls from industry for long-term perspectives on solution pathways for circularity, *constructive approaches* might be unable to materialize, which would argue for adopting an *agonistic approach* in the context of circular infrastructure. More details on these findings and approaches can be found in Chapter 3.

RQ 3 — *How can infrastructure stakeholders deliberatively anticipate future developments related to the CE mission?*

In the Dutch infrastructure sector, circularity was positioned as a transformative mission. Such missions have become a prominent approach to direct transitions in line with societal challenges. Due to the wicked nature of the societal challenges that these missions address, a structured governance approach is needed. Participatory, anticipatory, reflexive, and tentative governance modes can be used to deal with the wickedness' characteristics and mobilize stakeholders. Based on the traditions of Technology Assessment and Responsible Innovation, we developed the Mission-Oriented Transition Assessment (MOTA) as a collective appraisal of current and future socio-technical changes to inform stakeholders, particularly policymakers, on how to govern missions. Crucial to this approach is the use of socio-technical scenarios that enable stakeholders to deliberatively anticipate the potential socio-technical changes resulting from the mission-oriented transition. The MOTA has been applied to generate insights into the steps forward in the mission-oriented transitions towards circular infrastructure.

Contrarily to many other contexts, infrastructure clients have a dual role in the transition as both enactors and selectors of circular solutions, which puts them in an undisputed position as leaders in the transition. Moreover, findings stress the institutional and behavioural nature of the socio-technical change in the context of circular infrastructure, which requires stakeholders to innovate in the conditional processes and relationships that allow for circularity rather than mere technological solutions. Finally, there is a tension between incremental solutions that immediately increase circularity in projects (e.g., improving recycling efficiency) and radical solutions that are more challenging due to their systemic nature (e.g., closed supply-demand mechanisms for element reuse). While the former arguably risks creating lock-ins that prevent fundamental forms of circularity, the latter risks being too complex to achieve, even though it holds long-term potential for achieving circularity goals.

Infrastructure stakeholders should, therefore, focus on taking small, viable steps at a time while recognizing the radical change needed in the long term. This requires a careful balancing act between operationality and the radical nature of systemic change. Notable examples of frameworks that can support infrastructure clients are the *small wins framework* and *radical incrementalism*. Central to those approaches is the step-by-step way towards radically different – for instance circular – futures. Only then can the radical long-term nature of a circular infrastructure system be ensured without inducing standstills in the short term. Such perspectives leave major space for experimentation and innovation on local scales, for which infrastructure projects and pilots, particularly when organized in programmatic or portfolio settings, offer promising vehicles. While the infrastructure-specific outcomes serve stakeholders to better position themselves in the transition, policymakers can use the insights to identify the small steps worth considering to mobilize the stakeholder field in the mission-specific direction, for example, in line with specific solution pathways for specific types of infrastructure assets. Details on this approach and its application to circular infrastructure can be found in Chapter 4.

RQ 4 *How do infrastructure client organizations deal with the institutional pressures caused by the circularity transition?*

While, as discussed above, clients play a pivotal role in the circularity transition, fulfilling this role requires significant organizational transformation. On an organizational level, the developments towards circular infrastructure create institutional pressures that require organizations to transform and reconsider their value frame while maintaining their business operations. Rijkswaterstaat infrastructure agency is compelled to deal with the institutional pressures caused by implementing circularity policy as an inherently hybrid organization (i.e., an organization that embeds multiple institutional logics to deal with varying institutional contexts) concerning their infrastructure management processes. Results show how this results in tensions between logics related to circularity and logics inherent to the infrastructure management processes.

We found that the most impactful circularity opportunities are shaped during preliminary infrastructure management phases, while most efforts concentrate on the later stages. These include the planning and pre-project phases. The main reason is that the institutional logic adhered to by individuals that promote circularity is not embedded in those preliminary stages. We call this logic the *societal challenge logic*, which is insufficiently present in the pre-project stages of infrastructure works. This logic shows particular tensions with both the *state logic* that is dominant in the higher levels of the organization and the *asset management logic* that focuses on the operational stage of infrastructure. While the *societal challenge logic* is better suited to deal with the later stages, those later stages are strongly guided by the *project logic*. However, this project stage lacks the incentives to produce substantial circular solutions because of its fixed scope and limited time frame. Conflicts, especially in asset management and planning phases, thus hinder the integration of circularity principles throughout the infrastructure management process.

The clash between the *societal challenge logic* and the prevalent *state logic* calls for clear directives from management, necessitating an open debate on the roles of government and Rijkswaterstaat in particular. Attempting to embed circularity through hybridity alone is challenging due to entrenched conventional logics; clear directives from decision-makers are crucial for assimilating circularity goals into organizational practices. It is essential to engage circularity experts, who are guided by the societal challenge logic, early in the infrastructure management process. However, it must be acknowledged that the actual transformation hinges on broader desired organizational outcomes, which comprise the entire organization's value frame. The first steps to connect the logics are currently made in the studied organization, particularly in the shape of an integral circularity implementation programme that connects the various departments and layers throughout and beyond the organization. Deeper insights into the interaction between the various logics and the implications for organizational change are discussed in Chapter 5.

RQ 5 *How can the innovation ecosystem concept facilitate collaborations to innovate for challenges beyond the project context?*

A recurring finding of the studies addressing RQs 1, 3, and 4 was the project-based nature of the sector that impedes aiming for solutions beyond the project's scope, which resonates with the multi-lifecycle character inherent to circularity. A circular infrastructure system, therefore, needs other perspectives on inter-organizational relationships that facilitate the asset and project-crossing nature of circular material flows. The innovation ecosystem perspective offers a promising direction. This perspective allows for incorporating project-transcending goals and challenges in construction processes, mainly as it enables infrastructure stakeholders to build and maintain long-term relationships. Four characteristics that are unique to the innovation ecosystems perspective seemed crucial: (1) involvement of a heterogeneous set of actors; (2) strategic alignment of actors; (3) alignment with respect to a value proposition; and (4) relational governance structure. By applying these principles to five unconventional project-transcending initiatives in Dutch infrastructure, we drew several conclusions on how the innovation ecosystem concept can foster collaborations to facilitate innovation for challenges beyond the project context, including circularity.

Analyses of the initiatives show that adopting an innovation ecosystem perspective in the construction industry can be instrumental in addressing societal challenges such as circularity. As they focus on project-transcending value propositions, innovation ecosystems enable the introduction of solutions that surpass single supply chains. Results reveal that longer-term, cross-sectoral relationships, extending beyond conventional project-based supply chains, are better suited to produce innovative solutions. However, an innovation ecosystem perspective necessitates fundamental changes in inter-organizational governance, requiring a cultural shift from formal contractual arrangements to trust-based social ties in long-term collaborative relationships. This cultural and processual shift is, alongside novel technologies, arduous yet crucial for sector-wide systemic reconfigurations.

In sum, the innovation ecosystem perspective provides a promising starting point for understanding and establishing the conditions required to deal with the major societal and sectoral challenges. This collaborative transformation requires substantial effort in terms of experimentation, evaluation, and learning. Key factors are value-based contracting, partnering, procurement, risk, and profit allocation, and facilitating trust-based relationships. However, working in ecosystems will also substantially impact the economic systems and business models in which infrastructure actors operate. This requires substantial changes in the sector's working and collaboration cultures. Inevitably, these novel processes will continue to increase the complexity of the construction industry as a system. However, the alternative – remaining to work within single projects – seems inadequate to address the challenges at large. Details on the ecosystem perspective and comparison with the cases from infrastructure practice can be found in Chapter 6.

7.2 Navigating the circular infrastructure transition on three scales

The question of how the mission-oriented transition towards circular infrastructure can be governed depends strongly on the socio-technical system's characteristics and the transition goals. Connecting the research results to the lens of the multi-level perspective (MLP; Section 1.2.3), the transition towards a circular infrastructure sector results from external landscape pressures on the socio-technical regime (i.e., the configuration of (practices of) actors, institutions, and physical objects and technologies that comprise the Dutch infrastructure sector). Examples of such landscape pressures are supranational climate agreements and increasing supply risks. The highly political infrastructure regime is robust in terms of, for instance, rigid structural safety norms, the physical nature of infrastructure assets, and fixed stakeholder constellations. Besides, the dependence of other societal functions on infrastructure makes the sector invulnerable to sudden regime de-alignment. Therefore, emergent niche innovations have little chance to substitute existing socio-technical systems swiftly, and the circular regime is expected to develop from the existing linear one. As confirmed by the dispersed system of asset types, technologies, clients, and market parties in Chapter 2 (RQ 1) and the wealth of suggested solution directions in Chapter 3 (RQ 2), the transition will not be achieved by a single novelty that replaces non-circular technologies and practices. Instead, multiple configurations and sequences of solution components constitute the socio-technical system of a future circular infrastructure sector.

As a result, we may expect the transition towards a circular infrastructure sector, considering the typology of transition pathways by Geels and Schot (2007), to proceed as a sequence of the transformation and reconfiguration pathways. These pathway types have large consequences for how the diffusion of circularity knowledge and the upscaling of circular innovations should be steered and stimulated. After all, it means that socio-technical change occurs within the existing socio-technical regime and will only adopt partial solutions to the underlying transition challenges in circular infrastructure. This type of solution pathway has several implications for addressing the central research question of *how the mission-oriented transition towards circular infrastructure can be governed*. This section addresses this question on three scales: (1) sectoral, (2) inter-organisational, and (3) organizational scale. While the sectoral and inter-organizational scales are discussed through governance approaches and modes, the organizational and, to a lesser extent, inter-organizational scales are addressed from a management perspective. Together, these perspectives aim to breach the three vicious cycles identified in Study 1 (Chapter 2).

The sectoral scale

The complex and uncertain socio-technical transition towards a circular future is a joint challenge involving all stakeholders. The close interdependencies between the infrastructure stakeholders strengthen the need for a shared direction; however, this remains difficult due to the highly contested nature of the circularity mission. Throughout the research, it became clear that the general belief in the sector is that the government should lead the circularity transition in Dutch infrastructure. This call for a leading government arose not only because the challenges circularity aims to cover are represented in public values but also because the relation between public parties and market parties is inescapably hierarchical due to the client-contractor dichotomy in infrastructure. A client's leading role does not mean governments can solve contestation by enforcing or prescribing all next steps in circularity, nor can these clients one-sidedly install stricter procurement rules. Contrarily, this means that governments are responsible for encouraging and organizing the activities that lead to convergence to create awareness and support to converge towards a shared circular future eventually. This convergence, and eventually a progressing transition, can be stimulated in several ways.

First, *Reflexive governance* is a crucial governance mode in the mission governance framework (see Chapter 4). This governance mode primarily addresses the contestation involved in missions by encouraging reflection on societal contexts to reconsider existing practices and developments continuously. Tackling this contestation is particularly important, as it is a root barrier to the transition. Crucial in this 'reflexive stance' towards governance is that "it integrates a diversity of perspectives, expectations, and strategies in a complex understanding of societal change" (Voß & Bornemann, 2011, p.1). In infrastructure, such a reflexive governance approach could, for example, contribute to the collective reconsideration of public-private collaboration, infrastructure norms, and standardization efforts for circular design principles. Other non-exclusive governance modes that lay the basis for the mission governance framework – i.e., participatory, anticipatory, and tentative governance – are believed to provide aligned and socially robust transition outcomes. Moreover, they contribute to creating awareness among stakeholders and better preparing them for future changes. Results show that these governance modes, combined, offer an appropriate approach to navigate highly contested, uncertain, and contested mission-oriented transitions, such as the one towards circularity in Dutch infrastructure, for which MOTA offers an instrumental governance approach.

While navigating the transition, two general approaches can be distinguished to further deal with the high levels of contestation and uncertainty in the circularity transition from a government perspective. Either the *constructive* or the *agonistic governance approach* is promising in dealing with the contestation – depending on the degree and nature of the contestation. Here, *constructive approaches* are particularly suited for increasing insights into the contestation and stimulating convergence between the various perspectives (e.g., see Q-methodology in Chapter 3 and the MOTA approach in Chapter 4). In this context, Q-methodology can be utilized as a tool to both reveal the variety of perspectives on a particular wicked problem and confront the stakeholders with these perspectives, primarily aimed at structuring the problem and potential solutions. The *agonistic approach*, contrarily, promotes a governance approach in which decisions are made while recognizing that fundamental disagreements remain inevitable. This latter approach could be instrumental in enforcing decisions on prioritizing the many simultaneous yet competing societal challenges and potential solution directions. Results showed that, from a market perspective, such long-term-oriented decisions are crucial to justify the pre-investment for solution directions towards circular infrastructure. Nevertheless, when adopting an *agonistic approach*, it remains important to sustain dialogue throughout the process and with all stakeholders and remain transparent when making decisions in order to avoid eroding stakeholder support or even hostilities.

Considering the governance approaches discussed in Chapters 2 and 3, particularly the *agonistic approach* combined with the *small wins* or *radical incrementalism frameworks* seem suited to deal with the wickedness involved in the highly uncertain circularity transition. Here, the latter frameworks refer to taking feasible steps at a time while keeping an eye on the transition objectives. Infrastructure planning and budgeting are inevitably multi-decade endeavours that require long-term decisions. This creates an unavoidable tension that cannot be solved merely using tentative governance approaches. Although the literature on transformative governance does not provide us with a solution to this tension, several approaches in the infrastructure practice seem, at least partly, to deal with this (see Chapter 6). These approaches can be predominantly found in the programmatic approaches to infrastructure planning. These programmatic approaches prove particularly promising as they allow to establish long-term visions while maintaining the tentativeness needed to deal with uncertainties and complexities.

The inter-organizational scale

The view that the mission-oriented transition is a joint undertaking puts the present project-based approaches under pressure. In particular, the opposing and short-term public-private relationships make little sense when considering the enormous interdependencies between the stakeholders and the shared scarcities in capacity and funds. Chapter 6 shows how other ways of public-private collaboration are crucial to deal with challenges beyond the project scope. Here, the inclusion and strategic alignment of a heterogeneous group of participants appeared crucial to introduce the ideas necessary to deal with the wickedness involved in societal challenges, including circularity. However, the shared value proposition that enabled the collectives of infrastructure actors to translate goals from the longer term and sectoral scope into the scope of the collaboration turned out to be even more critical.

The strictly contractual relationships that dominate conventional infrastructure practice must be replaced by more relational ones to offer the flexibility required by the innovation processes that deal with the uncertainties involved. While the innovation ecosystem principles can take shape in many forms, promising points of departure are framework agreements, alliances, and programmatic approaches. Such approaches tackle the project-specific barriers and facilitate the networks necessary for industrial symbioses and component standardization, which are instrumental to establishing circular resource loops. Because of the asymmetrical relationships between government clients and market parties, the client organizations should initially facilitate such collaboration approaches. Nevertheless, this also requires substantial changes from market parties in behaviour and attitude – and eventually guiding values – to turn it into a success.

Finally, results show that, on an inter-organizational scale, there is fragmentation in clientship in infrastructure. Since market parties mainly act on a national scale, this runs the risk of creating competition between public clients, both for market capacity and ambitiousness regarding the circularity mission. This is particularly concerning in times of supply shortage, especially in terms of labour. To enable stakeholders to prepare for socio-technical changes imposed by the circularity mission, public clients must create a shared understanding and articulation of the circular infrastructure mission and its operationalization.

The organizational scale

Client organizations, as well as other actors in the construction supply chain, introduce many pilots and ideas on circular infrastructure, yet upscaling these pilots remains difficult. The study in Rijkswaterstaat revealed a lack of organizational processes that standardize circular outcomes and a struggle of individuals who draw from the *societal challenge logic* to integrally consider circular solutions within the organizational practices. The insights into the (mis)alignment between institutional logics revealed apparent mismatches between the organization's infrastructure management processes and the circularity implementation processes. Some employees even mentioned speaking different languages in different parts of the organization, resulting in a misapprehension of each other's practices and objectives. Above all, this confusion is substantial in infrastructure client organizations that must serve both the political bodies and the public-private operational practices.

Following the seminal work by Pache and Santos (2010), this dissertation offers an approach to determine how the inclusion of individuals that draw from the *societal challenge logic* can better secure the inclusion of circularity-based values in the organization's infrastructure management processes. This inclusion relates mainly to the asset management and the pre-project stages in infrastructure client organizations (e.g., budgeting and planning). More specifically, this means that people in organizations that adhere to one logic should be facilitated to become familiar with the other, which could practically be realised through, for example, a manager who participates for a short period of time in an asset management department. While executed in a single organization, similar misalignment patterns are expected to apply to other client infrastructure organizations working on circularity implementation. This finding likely extends beyond the Dutch borders since the internal varieties in institutional contexts and organizational structures of infrastructure clients around the globe are (while different in specifics) comparable in variety.

7.3 Implications for practice

These conclusions have several implications for practitioners in the various types of actors in the infrastructure domain. Below, implications are highlighted for governments as clients, asset owners, and policymakers, as well as for contractors and suppliers.

1. Government is in the lead for an aligned perspective. For owning and managing infrastructure, decentral and central governments are the primary clients and procurers of infrastructure. The results of our research stress the importance of aligning the perspectives on solution directions for circular procured solutions. Only then can the market parties pre-invest in the technologies and process changes that facilitate circular solutions beyond incremental project-specific solutions. Given that the majority of in-depth technological knowledge on infrastructure rests predominantly with market parties, the convergence of solution directions must not only be aligned between infrastructure clients but also involve market parties. An *agonistic approach* to governance seems applicable, given that the inherent contestation of circularity and conflicting interests will likely prevent sector-wide agreements on such asset-specific solution directions. Such *agonistic approaches* require strong leadership skills of the lead actors – i.e., governments.
2. Balancing short-term feasibility with long-term objectives. Because governments own the largest share of infrastructure assets, asset management principles must be aligned with circularity principles for becoming circular as an organization. Given the crucial aspect of linking resource flows beyond single asset lifecycles and projects, the planning and budgeting tasks must be coordinated more integrally to achieve circular outcomes in the long run. In doing so, keeping an eye on the tension between the tentativeness needed to deal with the wickedness and the long-term nature inherent to infrastructure is crucial. This requires a structured and continuous dialogue on circularity in the sector to shift from circular innovations and 'circular projects' towards integral perspectives on infrastructure networks and multiple asset lifecycles.
3. Mobilizing the sector through inclusive and anticipatory approaches. As governments act as policymakers, they are eventually responsible for mission-oriented transition governance. The conclusions of this dissertation offer several ways to avoid standstills and waiting games that result from the contestation of the circularity concept. In particular, the MOTA approach provides a tool to mobilize infrastructure stakeholders and inform policy. MOTA or alternative approaches that appreciate the complexity, uncertainty, contestation, and intractability of such wicked transitions can be used to structure the sectoral interactions that mobilize stakeholders. However, this can only be successful when acknowledging the role of the government as a catalyst for transformative change – which requires a

profound change in role perception (cf. Braams et al., 2021). This changing role perception is linked to a reconfiguration of institutional logics in client organizations and, specifically, the deliberate incorporation of the *societal challenge logic*.

4. Strategic advantage for pro-active contractors. Despite their dependence on public clients, contractors do not need to wait for clients' demand articulation for circularity. Instead, some future directions are evident, even though the exact solutions are not yet fully converged. When taking the initiative in such solutions, contractors might not only acquire a competitive advantage, but they also may be in the position to actively shape the circularity transition in which, in transition terms, their niche innovation could become central in the changed socio-technical regime. Another way for contractors to strategically better position themselves is through networking and co-creation, for which Chapter 6 offers several inspiring examples from Dutch practice. Finally, while holding off circularity as a contractor might be beneficial for the short term, it could prove fatal in the long run. After all, each transition not only knows *winners* but inevitably also *losers* since a new socio-technical system comes with new power balances (cf., Avelino & Wittmayer, 2016). In sum, knowing that the general directions of circularity and sustainability are unlikely to disappear, regardless of political changes or personal beliefs, a corporate change towards circularity will offer strategic advantages for contractors in the long run. At the same time, this is a call to industry leaders to prepare actors for the transitions ahead to avoid *losers* as much as possible – particularly considering the expected structural shortages in labour capacity.
5. Reconsidering the role of suppliers. Often overlooked in the circular infrastructure discussions are suppliers. Since the circularity objective to reduce supplies of new resources goes directly against their business models, suppliers inescapably must revise their role and position in the system. While a part of these suppliers remains necessary for the physical inability of the infrastructure sector to operate without virgin materials, even if these contain bio-based substitution materials, other suppliers might consider revising their business models much more towards connecting asset lifecycles in terms of waste flows. This latter change is very closely connected with the role of demolition contractors. The ecosystem perspective could be helpful for its ability to establish networks beyond single projects on a shared value proposition, for example, around material flows. It even might offer the opportunity for contractors to take a coordinating role with regard to material flows. These developments are not only strategically beneficial for environmental benefits, but they also reduce the dependence on geo-political developments and derived dependencies

on international supply chains with all their price, quality, and quantity fluctuations.

7.4 Theoretical contributions

The research in this dissertation was structured around a specific domain: the transition toward circular infrastructure. A wide range of theoretical lenses, concepts, and approaches were applied, adapted, and reflected upon to address the separate research questions. This approach has resulted in several contributions of the separate studies to various theoretical domains.

1. <u>Validation and refinement of the MIS framework.</u> In Chapter 2, we applied an early version of the MIS by Wesseling and Meijerhof (2021) that was later published separately (Wesseling & Meijerhof, 2023). Throughout the research, and specifically in Chapters 4 and 6, the importance of novel ways of stakeholder interactions emerged as a precondition for a circular system. This development did not fit the existing system functions. While Elzinga et al. (2023) made a promising start in consolidating a MIS framework, Chapter 2 contributes to validating and refining the MIS literature, mainly showing insights into applying the system functions to mission-oriented transitions. This contributes to transition studies and innovation policy and confirms the value of using frameworks to increase understanding of socio-technical systems in the context of missions.
2. <u>Operationalizing the problem-solution space.</u> The problem-solution space played an important role throughout the research, as it was used as the primary approach to separating the societal problems that circularity aims to address from the solution directions and points out the divergencies (Wanzenböck et al., 2020). However, a theoretical gap existed between the problem-solution space conceptualization and the actual contestation in practice. To address this gap, we operationalized the problem-solution spaces in Chapter 3 as “the plurality of contradicting, often undisclosed, imaginaries that shape conflict and practices in the present” (p. 61). Moreover, for its ability to map and deal with intersubjectivity involved in the diverging perspectives on circularity, we introduced the incorporation of the well-established Q-methodology with socio-technical imaginaries (cf., Dignum et al., 2016; Jasanoff & Kim, 2015). The approach presented in Chapter 3 can be used in any context where decision-makers need to gain insights into the contestation of societal challenges, either in support of mission governance or circularity. Doing so, this research contributes to various research fields, including Responsible Innovation and transformative governance.

3. A procedural approach for mission-oriented transition governance. Despite the considerable uptake of mission-oriented policies, there appeared to be a significant gap between the mission formulation and the implementation in practice. Past developments from the Technology Assessment have led to well-established methods for the diffusion of emergent technologies in wicked environments (e.g., Schot & Rip, 1997). Moreover, past research on Responsible Innovation has provided a procedural approach to better deal with epistemic and normative uncertainty involved in innovation (e.g., Stilgoe et al., 2013). We combined these two streams of literature with the recent stream on mission-oriented innovation policy (MIP) in Chapter 4. This resulted in addressing the implementation gap by offering a procedural approach to assist decision-makers in increasing social robustness, preparedness, awareness, and alignment of MIS stakeholders concerning a mission, called MOTA. These results are particularly relevant for the fields of transformative governance and STS. Insights in such exercises successfully inform stakeholders, particularly policymakers, on how to govern missions. Given its embeddedness in four governance modes that contribute to governing missions, this approach will likely apply to any context in which mission-oriented transitions are aimed to be supported.
4. The identification of the societal challenge logic. In Chapter 5, we applied the concept of institutional logics to the context of an infrastructure client. While making use of established logics as much as possible, the way logics were operationalized that referred to the behaviour of individuals that acted in favour of circularity (i.e., *sustainability logic* and *circularity logic*) were regarded unsuitable because those are content-laden and, therefore, by definition not universally applicable. Instead, we coined the *societal challenge logic* that refers to the guidance of behaviour by the moral responsibilities of adherents to contribute to society over the long term, striving for maximal societal impact without being tied to specific substantive content. Given the growing societal awareness of challenges, including climate change and globalization, this logic shows increasing relevance and applicability in explaining organizational change dynamics. This contribution is particularly relevant to scholars in organizational change theory and public management but could also provide relevant insights to scholars interested in CE and sustainability governance.
5. The innovation ecosystem perspective in construction. Finally, the term *ecosystem* is increasingly used in construction literature but without any conceptual foundations. By offering a theoretical framework to understand innovation ecosystems in the infrastructure context, we provided a theoretical basis in Chapter 6 for formulating and assessing innovation ecosystems in the context of infrastructure. This contribution lies mainly in

the novel applications of business and management literature in the construction management domain. While it might provide a new context relevant to organizational scientists, the results are expected to be especially relevant to construction management scholars.

7.5 Outlook to future research

While studying the complex and uncertain transition towards achieving "circular infrastructure by 2050" in the Netherlands, I have identified several opportunities that invite further exploration.

A critical area for future investigation is the nuanced interplay between various missions and societal challenges (Warbroek et al., 2023). Albeit crucial, circularity is just one of the missions or strategies to future-proof the infrastructure sector. How different transitions, such as the ones related to energy, digitalization, and circularity, interact and impact each other remains largely unexplored in the literature. Understanding these dynamics will be crucial in developing coherent strategies that harmonize varying sustainability goals towards a future-proof infrastructure sector. This alignment issue invites research questions such as: What are the implications of advancements in one mission-oriented transition on the strategies and outcomes of another? How can policy coherence be achieved among various missions to avoid conflicting outcomes? And how do particular missions contribute to addressing the many impact categories?

The intersection of politics, governance, and infrastructure emerges as a complex domain needing deeper insights, particularly considering the tension between physical infrastructure's long-term nature and mission governance's required tentativeness (cf. Kuhlmann et al., 2019). The challenging alignment between multi-lifecycle infrastructure planning and budgeting, on the one hand, and political lifespans, on the other, present an important area for exploration. Research could focus on the implications of shifting power dynamics and the concept of transition politics from a multi-actor perspective. Future research could provide insights into the consequences of changing power relations in the transition towards circular infrastructure, for example, in line with the concept of transition politics from a multi-actor perspective (Avelino & Wittmayer, 2016). A question to explore could be: How can multi-actor transition politics be effectively navigated to align with long-term sustainability goals in infrastructure?

Many long-term circularity goals boil down to higher-order environmental impact categories, including carbon and waste reductions and relate to supranational goals, such as the Sustainable Development Goals (SDGs). Given the abovementioned misalignment of these long-term goals with political timeframes, as well as the coordination failures between governments on various scales, this research has confirmed the difficulties with offering long-term perspectives needed to mobilize stakeholders to accelerate the circularity transition. This research shows that setting such direction on regional, sectoral, or even national scales is nearly impossible. To maintain the level playing field needed to mobilize markets, a regulatory body decoupled from the political arena could, with the proper mandates, offer long-term perspectives for the underlying sustainability goals. To gain such insights, future studies must investigate the potential benefits and limitations, as well as the governance structures to accommodate such a regulating body, for example, in the shape of a supranational institute. Despite serving a different context, an exceptional example of a long-term-oriented supranational institute is the technocratic European Central Bank (ECB), which offers price stability beyond the political cycles of individual member countries yet is accountable to the democratically elected European Parliament.

The decisiveness of the social and institutional preconditions for circularity, rather than specific technological solutions, highlights the need for a broader research outlook. Insufficient insights into the consequences of upscaling or dominance of one solution pathway over the other might cause a suboptimal, locked-in end-system as the best achievable outcome (cf. Geels et al., 2004; Goldstein et al., 2023). Due to the acknowledged wickedness that affects such transitions, recent developments in transition governance building upon the principles of reflexivity and tentativeness are promising. These stress the importance of facilitating deliberative anticipation of potential futures rather than its prescription. Future research is needed to understand the systemic and relational aspects of particular solution pathways, exploring how different stakeholders, practices, and policies interact towards the mission of circular infrastructure. Research questions arise, such as: How can fundamentally circular solutions be distinguished from solutions that result in suboptimal lock-ins? And what are the systemic consequences of prioritizing specific circularity solution pathways over others?

The lack of distance-to-target insights appeared to be a central issue in steering for circular infrastructure. As most circularity benefits for infrastructure will only manifest in several decades, it is hard to allocate such benefits in the future to present choices and investments. Many existing monitoring approaches focus on resource flows. Future research is needed on assessing and monitoring circularity developments to better steer for solution directions, interventions, and resource allocation, particularly in sectors with long-lifespan objects, such as infrastructure. This research would address research questions, such as: How can monitoring systems account for the long-term benefits of circularity? And how can the benefits of circular solutions be assessed in the socio-technical context considering the wickedness of missions? A promising starting point is the shift in focus from resource outputs to the activities and socio-technical changes that facilitate the conditions for circular choices of operational activities in the long run, which, for instance, is partly used by the Dutch Environmental Assessment Agency (PBL).

Public organizations are usually guided by sets of values that aim at stability and continuity and depend on political cycles. As such, these organizations are intrinsically ill-equipped to deal with long-term challenges such as circularity. While a considerable amount of literature exists on how such public organizations could transform to render their business operations sustainable or even circular (cf. Kristensen et al., 2021), insights are lacking on how these organizations could instil systemic change. Such insights, or even action perspectives, require further research that addresses questions such as: How can public client organizations align their business processes with long-term transition processes? And how can public client organizations promote systemic change beyond their direct client-contractor relationships?

In sum, this dissertation provides insights and ways to better transition towards a circular infrastructure sector. It has unveiled both the complexities and opportunities and serves as a foundation and a call for further multi-disciplinary exploration. The transition ahead demands a carefully governed effort to deal with – or even embrace – the wickedness involved, which includes innovative governance models and systemic thinking. Such approaches are crucial in shaping an inherently circular infrastructure for the future. In its exploration and findings, this dissertation invites researchers, policymakers, and industry leaders to continue the exploration. I hope it provides a starting point for probing deeper into the socio-technical dynamics that will define and hopefully offer grounds to materialize the joint ideals towards a sustainable society that operates within the limits of the Earth.

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appendices

Appendix 1.1. Circularity solutions in infrastructure

This appendix presents an excerpt from the paper *CEIMA: A framework for identifying critical interfaces between the Circular Economy and stakeholders in the lifecycle of infrastructure assets*[1] by Coenen et al. (2020), in which we designed a framework that enables infrastructure stakeholders to get started with circularity principles from the perspective of their assets. In what follows, we show the part of Section 4.2 of the paper that presents an overview of the identified circularity strategies and related infrastructure-related actions.

4.2. Solution principles

In this section, the CE principles according to which the framework will be designed are presented. Due to the comprehensiveness of the definitions presented in the section on CE, we consider them to be too abstract for the specific context of this study, since they include concepts that are difficult to operationalize from a bottom-up perspective. Because there are various principles underlying the definition of a CE, it can be considered as an umbrella concept (Blomsma & Brennan, 2017). In order to arrive at interfaces which are practically implementable, the overall concept needs to be parsed into specific chunks to allow for systematic analysis of the interfaces between CE and the infrastructure domain.

Although we acknowledge the need for a system-wide transition rather than individual innovations to render the system fully circular, we stress the need for a fast and concrete operationalization that enables professionals to get acquainted with the concept. In order to achieve this, practical approaches towards circularity are derived from the "9R" waste hierarchy by means of decomposition. The "9Rs" are still too abstract to offer a concrete plan of action for professionals. Below, these rather abstract "9R" strategies are translated into concrete actions towards circular practices. The aim of this list is not to be exhaustive, but to provide suggestions for the most important areas of action. The figure on the next page shows the linking of actions to the "9R" hierarchy and includes notes and references accompanying the particular actions.

The strategies are based on Bovea and Pérez-Belis (2018), Iacovidou and Purnell (2016), Kirchherr et al. (2017), Lansink (2017), Lieder et al. (2017), Martinetti et al. (2015), Mulder et al. (2014), Pauli (2015), Schmidt (2014), and Stahel (2013).

[1] Published as "Coenen, T. B. J., Haanstra, W., Jan Braaksma, A. J. J., & Santos, J. (2020). CEIMA: A framework for identifying critical interfaces between the Circular Economy and stakeholders in the lifecycle of infrastructure assets. Resources, Conservation and Recycling, 155. https://doi.org/10.1016/j.resconrec.2019.104552"

	CE Strategy
Smarter use and construction	**R0: Refuse** abandon or avoid function
	R1: Rethink make more use of functionality
	R2: Reduce increase construction and usage efficiency
Lifespan extension of entities	**R3: Reuse** reuse in new lifecycle
	R4: Repair bring entity to initial state and functionality
	R5: Refurbish restore end-of-life product to become functional again
	R6: Remanufacture use elements of discarded entity with the same function
	R7: Repurpose use discarded entity in a new (lower) function
Useful application of materials	**R8: Recycle** process materials to be used in a new lifecycle
	R9: Recover energy recovery

Actions

(1) Reconsider necessity of asset

(2) Increase quality for longer lifespan
(3) Multi-functional use
(4) Increase adaptability
(5) From product sales to products-as-a-service

(6) Develop low-material solutions
(7) Develop low-energy solutions
(8) Use recycled materials
(9) Use waste from other assets
(10) Policies for resource reduction

(11) Consider assets and components for reuse
(12) Design-for-Deconstruction
(13) Match supply and demand

(14) Smart maintenance strategies
(15) Repair defect asset
(16) Design-for-Maintenance

(17) Restore asset or parts to be reused
(18) Restore parts to be reinstalled in entity
(19) Couple EoL to new lifecycle
(20) Match supply and demand
(21) Align with norms and legislation

Sources and notes accompanying actions

Lansink (2017) stresses pre-design considerations regarding necessity of resource use

Kirchherr et al. (2017) suggest various ways to rethink the system. Schmidt (2014) shows the various ways to increase adaptability in building construction.

Stahel (2013) advocates policies for resource reduction. Lieder and Rashid (2016) put emphasis on critical resources (Lieder and Rashid, 2016). Pauli (2015) stresses the need for using waste from other processes as input.

Bovea & Pérez-Belis (2018) discuss various design options for the use and EoL phase. The various prerequisites for asset reusability are elaborated on by Iacovidou and Purnell (2016)

Maintainability and repairability by means of design are strongly advocated by Martinetti, Braaksma and Van Dongen (2015) and Mulder et al. (2014). Xing and Marwala (2018), moreover, stress the need for thoughtful maintenance strategies and techniques.

Appendix 2.1. List of grey literature.

No.	*Source document*
Policy documents	
1	Transitieteam Bouw, 2018. Transitie-agenda circulaire bouweconomie. [Transition agenda circular construction economy.]
2	Provincie Overijssel, 2020. Samen krijgen we de Twentse cirkel rond! [Together we close the Twentse loop!]
3	Transitieteam Bouw, 2018. Naar een circulaire bouweconomie: Uitvoeringsprogramma 2019. [To a circular construction economy: implementation program 2019.]
4	Transitieteam Bouw, 2019. Naar een circulaire bouweconomie: Uitvoeringsprogramma 2020. [To a circular construction economy: implementation program 2020.]
5	Ministerie van IenW, 2020. Bijlagen I, II, II bij het Uitvoeringsprogramma Circulaire Economie 2020-2023. [Appendices I, II, III to the Implementation programme Circular Economy 2020-2023.]
6	Rijkswaterstaat, 2020. Jaarrapportage 2019: Impulsprogramma Circulaire Economie. [Annual report 2019: Impulsprogramma Circular Economy].
7	Ministerie van IenW, 2020. Strategie “Naar klimaatneutrale en circulaire rijksinfraprojecten”. [Strategy “to climate-neutral and circular national infrastructure projects”.]
8	Ministerie van IenW, 2015. Beleidsverkenning Circulaire economie in de Bouw. [Circular economy in the Dutch construction sector.]
Industry and sector documents	
9	CB’23, 2021. About platform CB’23. Retrieved from: http://www.platformcb23.nl/english (September 2021).
10	Cirkelstad, 2021. Green paper – nieuwe spelregels in de bouw: Circulair bouwen na Corona [Green paper – New construction rules: Circular construction after Corona].
Cross-sectoral publications	
11	Circle Economy, 2020. The circularity gap report: The Netherlands
12	Rijksoverheid, 2016. Nederland circulair in 2050. [The Netherlands circular in 2050.]
Agreements	
13	Grondstoffenakkoord, 2017. Intentieovereenkomst om te komen tot transitieagenda’s voor de Circulaire Economie. [Letter of intent to develop transition agendas for the Circular Economy.]

Appendix 2.2. List of interviewees.

No.	*Interviewee Type*
Public client organizations (governmental organization)	
1	Programme manager infrastructure at Dutch province[2]
2	Programme manager Rijkswaterstaat
3	Programme manager Rijkswaterstaat[2]
4	Policy coordinator water board association[1]
Ministries (civil servants)	
5	Coordinator Ministry of Interior and Kingdom Relations[1,2]
6	Policy officer Ministry of Infrastructure and Water Management[1,2]
7	Coordinator Ministry of Infrastructure and Water Management[1]
Industry (industry organization)	
8	Consultant sustainable and circular construction[2]
9	Consultant sustainable and circular construction[2]
10	Consultant sustainable and circular construction[2]
11	Sustainability coordinator contractor organization
12	Project coordinator contractor organization
13	Consultant sustainable and circular construction[1,2]
Knowledge institutions	
14	Asphalt expert independent research organization
15	Circular infrastructure scholar[2]
Network organizations, platforms, and associations (network organization)	
16	Director circularity network organization[1,2]
17	Sustainability manager industry association[1,2]
Financial, legal, and process experts (experts)	
18	Economic expert sustainable construction
19	Legal expert sustainable construction
20	Standardization expert[1]

[1] Is/was affiliated with the Transition Team mission arena
[2] Is/was affiliated with the CB'23 mission arena

Appendix 3.1. Q-statements as input for the Q-survey.

	No.	Statements
Problem-oriented	1	Circular construction provides lower particulate emissions than linear construction
	2	One of the goals of circularity in the construction industry is to reduce greenhouse gas emissions
	3	Circularity has the potential to contribute greatly to solving the nitrogen crisis in construction
	4	Circular construction addresses the problem of waste production
	5	With circular construction, we avoid the depletion of our earth
	6	The problem of linear construction lies mainly in the use of primary resources
	7	Circular construction is necessary to combat the decline of biodiversity
	8	Circular construction reduces the risk of water shortages in the Netherlands
	9	Circular construction helps reduce CO2 emissions to meet the Netherlands' climate goals
	10	With circular construction, we can reduce unnecessary material losses in the supply chain
	11	Circular construction benefits the water quality of the Netherlands
	12	Circular construction can prevent health damage by better handling toxic materials
	13	Circular construction can reduce the sector's energy consumption
	14	The core problem that circular construction addresses is environmental impact and climate change
	15	Circular construction contributes to reducing social inequalities in our society
	16	With circular construction, the industry's supply risks of materials and components can be decreased
	17	Circular construction contributes to achieving a climate-neutral society
	18	Circular construction is primarily a means to reduce greenhouse gas emissions
Solution-oriented	19	In a circular construction, down cycling of materials is inevitable
	20	Circular construction requires that a large portion of the materials used be bio-based
	21	Modular design is essential for circular construction
	22	The construction sector must focus on recycling to become circular
	23	A reduction in the use of primary resources must be a priority for circular construction
	24	The construction sector must commit to reusing components to become circular
	25	Circular construction requires new monitoring and measurement systems that can be used to manage circularity
	26	In order to realize a circular construction, suppliers and contractors must ultimately become responsible for assets over their entire lifecycle
	27	Circular construction starts with thinking about how to use resources efficiently

	28	Material and design strategies should focus on the highest possible R-strategy on the "R-ladder
	29	Circular construction must focus primarily on extending the life of assets
	30	As-a-service business models play a key role in kick-starting the transition to circular construction
	31	A carbon tax is a crucial measure to accelerate the transition to a circular construction sector
	32	Future circular projects should focus on avoiding material use as much as possible
	33	Circular construction should focus on reducing waste production
	34	Circular construction requires that assets are designed for disassembly
	35	Material passports are necessary to realize circular construction
	36	New standards and guidelines are needed to facilitate circular construction
	37	In circular initiatives, more focus is needed on sustainable materials
	38	Circular construction should establish residual value based on the actual physical condition of assets rather than their depreciation period
	39	Circular construction requires substantial changes in current laws and regulations
	40	Climate adaptive building contributes to achieving circular construction
	41	Circular construction will need to focus more on the ‘cradle-to-cradle’ strategy
	42	Block chain can play an important role in making circular construction a reality
	43	A circular construction sector will have to strive to upcycle materials
	44	Procurement strategies are essential tools for achieving circular assets
	45	Reducing the material demand requires changes in our lives, for example by living smaller

Appendix 3.2. List of respondents

List of respondents, including their actor (sub-)type and statistically significant factor loadings. 'No flag' denotes significant correlations of respondents with imaginaries other than their most fitting imaginary.

No.	*Significant factor loading*	*Actor type*	*Sub-type*	*Job description of respondent*
R1	1	Industry	Contractor	Department head sustainability
R2	1, 3 (no flag)	Industry	Contractor	Project manager sustainability
R3	2	Industry	Contractor	Chief commercial officer
R4	-	Industry	Supplier	Consultant
R5	3	Industry	Supplier	Manager
R6	3, 1 (no flag)	Construction clients	Public commissioner	Innovation consultant infrastructure
R7	3	Construction clients	Public commissioner	Consultant circular economy
R8	-	Construction clients	Public commissioner	Senior consultant circular economy
R9	1	Construction clients	Public commissioner	Technical manager
R10	3, 2 (no flag)	Construction clients	Public commissioner	Head of district
R11	1	Construction clients	Public commissioner	Senior consultant circular economy
R12	2	Construction clients	Public commissioner	Senior consultant circular economy
R13	3	Construction clients	Public commissioner	Asset manager
R14	2, 1 (no flag)	Construction clients	Public commissioner	Coordinator sustainability
R15	3 ,2 (no flag)	Construction clients	Public commissioner	Sustainability monitoring
R16	1	Construction clients	Public commissioner	Sustainability consultant

R17	1, 3(no flag)	Construction clients	Public commissioner	Transition director circular public spaces
R18	2	Construction clients	Public commissioner	Ambassador circularity
R19	2,1 (no flag)	Policy	Policymaker	Program secretary
R20	2	Researchers	University	PhD candidate circular construction
R21	1, 2 (no flag)	Researchers	University	PhD candidate circular construction
R22	1, 2 (no flag)	Researchers	University	Full professor
R23	1 ,3 (no flag)	Researchers	University	Assistant professor circular construction
R24	2, 1 (no flag), 3 (no flag)	Researchers	University	PhD candidate circular infrastructure
R25	1	Researchers	Research institute	Procurement expert dredging technology
R26	1	Advisory firms	Engineering firm	Lead engineer
R27	-	Advisory firms	Engineering firm	Director circular and bio-based solutions
R28	1, 3 (no flag)	Advisory firms	Engineering firm	Architect
R29	3	Advisory firms	Engineering firm	Business director circular economy
R30	3	Advisory firms	Engineering firm	Circular design manager
R31	2	Advisory firms	Consultancy	Consultant
R32	1	Infrastructure	Networks	Consultant sustainable construction
R33	2	Infrastructure	Networks	Manager
R34	-	Infrastructure	Banking	Business developer circularity

Appendix 3.3. Factor arrays based on the survey responses.

	No.	*Statements*	*Factor 1*	*Factor 2*	*Factor 3*
Problem-oriented	1	Circular construction provides lower particulate emissions than linear construction	-3	-1	-4
	2	One of the goals of circularity in the construction industry is to reduce greenhouse gas emissions	1	0	-1
	3	Circularity has the potential to contribute greatly to solving the nitrogen crisis in construction	-3	-2	-1
	4	Circular construction addresses the problem of waste production	0	-4	-2
	5	With circular construction, we avoid the depletion of our earth	5	5	3
	6	The problem of linear construction lies mainly in the use of primary resources	0	-2	1
	7	Circular construction is necessary to combat the decline of biodiversity	-2	-3	-2
	8	Circular construction reduces the risk of water shortages in the Netherlands	-5	-3	-5
	9	Circular construction helps reduce CO2 emissions to meet the Netherlands' climate goals	1	2	0
	10	With circular construction, we can reduce unnecessary material losses in the supply chain	1	1	2
	11	Circular construction benefits the water quality of the Netherlands	-5	-4	-4
	12	Circular construction can prevent health damage by better handling toxic materials	-1	-1	-3
	13	Circular construction can reduce the sector's energy consumption	-1	0	0
	14	The core problem that circular construction addresses is environmental impact and climate change	3	3	-1
	15	Circular construction contributes to reducing social inequalities in our society	-4	-4	-5
	16	With circular construction, the industry's supply risks of materials and components can be decreased	-1	-1	1
	17	Circular construction contributes to achieving a climate-neutral society	5	3	-2
	18	Circular construction is primarily a means to reduce greenhouse gas emissions	-2	0	-4
Solution-oriented	19	In a circular construction, down cycling of materials is inevitable	-1	-5	-3
	20	Circular construction requires that a large portion of the materials used be bio-based	-1	0	-3
	21	Modular design is essential for circular construction	0	4	4
	22	The construction sector must focus on recycling to become circular	-2	-5	-2
	23	A reduction in the use of primary resources must be a priority for circular construction	4	1	5

	24	The construction sector must commit to reusing components to become circular	1	3	3
	25	Circular construction requires new monitoring and measurement systems that can be used to manage circularity	0	3	5
	26	In order to realize a circular construction, suppliers and contractors must ultimately become responsible for assets over their entire lifecycle	-4	-2	-3
	27	Circular construction starts with thinking about how to use resources efficiently	4	4	2
	28	Material and design strategies should focus on the highest possible R-strategy on the "R-ladder	3	5	1
	29	Circular construction must focus primarily on extending the life of assets	1	1	0
	30	As-a-service business models play a key role in kick-starting the transition to circular construction	-3	0	0
	31	A carbon tax is a crucial measure to accelerate the transition to a circular construction sector	0	2	-1
	32	Future circular projects should focus on avoiding material use as much as possible	2	1	0
	33	Circular construction should focus on reducing waste production	2	-3	1
	34	Circular construction requires that assets are designed for disassembly	0	4	4
	35	Material passports are necessary to realize circular construction	-2	2	3
	36	New standards and guidelines are needed to facilitate circular construction	2	-1	2
	37	In circular initiatives, more focus is needed on sustainable materials	3	-1	0
	38	Circular construction should establish residual value based on the actual physical condition of assets rather than their depreciation period	3	1	3
	39	Circular construction requires substantial changes in current laws and regulations	1	0	2
	40	Climate adaptive building contributes to achieving circular construction	-3	-3	-1
	41	Circular construction will need to focus more on the 'cradle-to-cradle' strategy	4	0	0
	42	Block chain can play an important role in making circular construction a reality	-4	-2	-1
	43	A circular construction sector will have to strive to upcycle materials	2	1	1
	44	Procurement strategies are essential tools for achieving circular assets	0	2	4
	45	Reducing the material demand requires changes in our lives, for example by living smaller	-1	-1	1

Appendix 3.4. Factor loadings of respondents per factor.

Factor loadings of respondents per factor. (X) denotes a respondents highest statistically significant factor loading.

No.	*Factor 1*	*Factor 2*	*Factor 3*	*Actor type*	*Sub-type*
R1	0.55151 (X)	0.22275	0.33380	Industry	Contractor
R2	0.54937 (X)	-0.03046	0.40704	Industry	Contractor
R3	-0.05025	0.48709 (X)	0.27687	Industry	Contractor
R4	0.30169	0.01773	0.13445	Industry	Supplier
R5	0.07233	0.12408	0.56173 (X)	Industry	Supplier
R6	0.42533	0.22807	0.59774 (X)	Construction clients	Public commissioner
R7	-0.08084	0.09090	0.45189 (X)	Construction clients	Public commissioner
R8	0.25379	0.36412	0.33996	Construction clients	Public commissioner
R9	0.63375 (X)	0.16557	0.02567	Construction clients	Public commissioner
R10	-0.00866	0.53135	0.54385 (X)	Construction clients	Public commissioner
R11	0.39299 (X)	0.27490	0.22987	Construction clients	Public commissioner
R12	0.23892	0.65721 (X)	0.27360	Construction clients	Public commissioner
R13	0.26348	0.06243	0.62832 (X)	Construction clients	Public commissioner
R14	0.39348	0.43647 (X)	0.12564	Construction clients	Public commissioner
R15	0.24948	0.38568	0.46627 (X)	Construction clients	Public commissioner
R16	0.65541 (X)	0.01612	0.18343	Construction clients	Public commissioner
R17	0.49496 (X)	0.24586	0.48728	Construction clients	Public commissioner
R18	0.19378	0.61395 (X)	0.07042	Construction clients	Public commissioner
R19	0.43198	0.56330 (X)	0.33155	Policy	Policymaker
R20	0.35224	0.59180 (X)	0.13472	Researchers	University
R21	0.55424 (X)	0.48054	0.00560	Researchers	University

R22	0.55052 (X)	0.40306	0.10487	Researchers	University
R23	0.53711 (X)	0.03574	0.41175	Researchers	University
R24	0.47150	0.50222 (X)	0.40131	Researchers	University
R25	0.60337 (X)	0.18742	0.24264	Researchers	Research institute
R26	0.66228 (X)	0.13766	0.08904	Advisory firms	Engineering firm
R27	-0.09326	0.18549	-0.0236	Advisory firms	Engineering firm
R28	0.54702 (X)	0.11916	0.48511	Advisory firms	Engineering firm
R29	0.20635	0.35942	0.48966 (X)	Advisory firms	Engineering firm
R30	0.28114	0.38166	0.41516 (X)	Advisory firms	Engineering firm
R31	0.21067	0.47160 (X)	0.23214	Advisory firms	Consultancy
R32	0.58548 (X)	0.10489	-0.18248	Infrastructure	Networks
R33	0.06040	0.53825 (X)	0.11735	Infrastructure	Networks
R34	0.37597	0.37512	0.02973	Infrastructure	Banking

Appendix 5.1. Characteristics of the four identified logics

Characteristics of the four identified logics. Authors' elaboration on Farid and Waldorff (2022), Jay (2013), and Thornton et al. (2005).

Characteristic	*State logic*	*Asset management logic*	*Project logic*	*Societal challenge logic*
Planning frame	Permanent / political cycle	Permanent / asset lifespan	Temporary / project duration	Long-term future
Organizing structure	Bureaucratic hierarchy	Matrix	Integrated project team	Flat hierarchy
Structural composition	Stable group of bureaucrats with rotating executives	Stable teams with regional autonomy managing a stable geography-determined group of assets	Temporary and dynamic teams comprising specific experts for the specific challenges	Stable teams with dynamic tasks following the latest societal developments and policy statements
Actor context	Bridge between Ministry and infrastructure organization	Local stakeholders, engineering and advisory firms, Ministry	Experts, engineering and advisory firms, market parties	Ministry, other governments, consultancies
Organizational goals/purposes	Policy execution	Service delivery	Project delivery	System change
Basis of strategy	Increase legitimacy	Increase effectivity	Increase efficiency	Increase future preparedness
Guiding values	Accountability, transparency, impartiality, democracy	Continuity, integrality, long-term effectivity, collaboration	Cost efficiency, professionality, task delivery	Leadership, sustainability, system change, autonomy
Value creation activities	Translating political and administrative priorities into operational tasks	Managing infrastructure assets; activities based on assets' state and norms	Execute project; engineering; activities based on assigned tasks	Prepare and create knowledge base and conditions for organizational transformation
Dominant disciplines	Public administration; law; political science	Engineering; management	Engineering; public administration; management	Social science; sustainability science; highly diverse

Ideal type department	Executive staff	Regions	Project units	Knowledge department
Organizational purpose	Execute political demands	Provide mobility infrastructure	Provide mobility infrastructure	Serve broad society
Material artifacts	Protocols and procedures	Service-level agreements, management contracts, (technical) norms	Project scope forms, (technical) norms	Knowledge reports, formal policy, and strategy documents
Illustrative quotes	“My tasks are managed within the hierarchy, […] so the department receive assignments from the [Ministry] and we need to carry them out” (CD1)	“I am already looking [at CE] and express my wishes, because if it leads to cost savings on the long term, I can make my assets more valuable” (RD1)	“If the planning phase is finished, […] I need to provide an estimate of what I think the project will ultimately cost in execution.” (LP7)	“I do things that energize. […] That can be any societal value that I align myself with. So that is very closely linked with my personal view – and even political one” (LP2)

Overview of published and under-review materials

Journal publications used as separate chapters in dissertation:

- Coenen, T.B.J., Visscher, K., & Volker, L. (2023). **A systemic perspective on transition barriers to a circular infrastructure sector.** Construction management and economics, 41(1), 22-43. https://doi.org/10.1080/01446193.2022.2151024 (Chapter 2)
- Wiarda, M.J., Coenen, T.B.J., & Doorn, N. (2023). **Operationalizing contested problem-solution spaces: The case of Dutch circular construction**. Environmental Innovation and Societal Transitions, 48, 100752. https://doi.org/10.1016/j.eist.2023.100752 (Chapter 3)
- Coenen, T.B.J., Wiarda, M.J., Visscher, K., Penna, C.C.R., & Volker, L. (under review). **Mission-Oriented Transition Assessment** (Chapter 4)
- Coenen, T.B.J., Frederiksen, N., Volker, L., & Visscher, K. (under review). **Navigating institutional plurality in pursuit of a circular economy: The case of a public infrastructure organization** (Chapter 5)
- Vosman, L., Coenen, T.B.J., Volker, L., & Visscher, K. (2023). **Collaboration and innovation beyond project boundaries: exploring the potential of an ecosystem perspective in the infrastructure sector**. Construction management and economics. https://doi.org/10.1080/01446193.2023.2165695 (Chapter 6)

Other journal papers written/contributed during PhD trajectory:

- Wiarda, M.J., Janssen, M.J., Coenen, T.B.J., & Doorn, N. (2024). **Responsible Mission Governance: An Integrative Framework and Research Agenda.** Environmental Innovation and Societal Transitions, 50, 100820. https://doi.org/10.1016/j.eist.2024.100820
- Coenen, T.B.J., Santos, J., Fennis, S.A.A.M., & Halman, J.I.M. (2021). **Development of a bridge circularity assessment framework to promote resource efficiency in infrastructure projects**. Journal of industrial ecology, 25(2), 288-304. https://doi.org/10.1111/jiec.13102
- Coenen, T.B.J., Haanstra, W., Braaksma, A.J.J., & Santos, J. (2020). **CEIMA: A framework for identifying critical interfaces between the Circular Economy and stakeholders in the lifecycle of infrastructure assets**. Resources, conservation and recycling, 155, [104552]. https://doi.org/10.1016/j.resconrec.2019.104552

- Eikelenboom, M., Van Uden, M.F.M., & Coenen, T.B.J. (under review). **Strategic programmes for circular construction: lessons from three public clients.**
- Sobota, V.C.M., Wiarda, M.J., Coenen, T.B.J., and Ortt, R. (under review). **How Can Platform Ecosystems Support Mission-Oriented Innovation?**

Peer-reviewed conference contributions:

- Coenen, T.B.J., Volker, L., & Visscher, K. (2023). **Circular infrastructure in terms of institutional logics.** In: Proceedings of the 39th annual ARCOM conference.
- Coenen, T.B.J., Wiarda, M.J., Visscher, K., Volker, L., & Penna, C. (2023). **Mission-Oriented Transition Assessment**. Annual Eu-SPRI conference 2023.
- Coenen, T.B.J., Visscher, K., & Volker, L. (2023) **Circularity in the built environment: A goal or a means?** In: SDGs in Construction Economics and Organization. Lindahl, G., Gottlieb, S.C. (eds). Springer Verlag (pp. 253-268).
- Coenen, T.B.J., Visscher, K., & Volker, L. (2022). **Circular economy or circular construction? How circularity is understood by construction practitioners**. In: Proceedings of the 38th annual ARCOM conference (pp. 552-561).
- Coenen, T.B.J., Visscher, K., & Volker, L. (2021). **Appraising the mission-oriented innovation system framework in practice: The transition towards a circular infrastructure sector.** Eu-SPRI Early Career Conference, Paris, 2021.
- Vosman, L., Coenen, T.B.J., Volker, L., & Visscher, K. (2021). **Exploring the innovation ecosystem concept for a construction industry in transition**. In: Proceedings of the 37th Annual ARCOM Conference (pp. 449-458). (received Best Paper Award)
- Coenen, T.B.J., Volker, L., & Visscher, K. (2021). **Introducing circular innovation in the construction industry: The case of the circular viaduct**. In: Proceedings of the 37th Annual ARCOM Conference (pp. 624-633).
- Coenen, T.B.J., Vosman, L., Volker, L., & Visscher, K. (2021). **Projects as temporal configurations within innovation ecosystems: evidence from the construction industry**. 37^{th} EGOS Colloquium

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About the author

Tom Coenen was born in Helden, The Netherlands, on May 18th, 1993. After finishing his Bachelor's degree in Civil Engineering and Master's degree in Construction Management & Engineering at the University of Twente, Tom completed an engineering doctorate (EngD) in circular design of bridges and viaducts at the same university. After a three-month bridging period as the secretary of the collaboration platform 4TU.bouw, he started a PhD trajectory funded and supported by Rijkswaterstaat in 2020, of which the resulting dissertation lies before you.

Apart from the research and publication activities related to the PhD project, he was the principal teacher in a Bachelor's course on sustainability and circularity in construction and co-developed and taught a Master's course on transitions in civil engineering. During this period, he supervised several Bachelor's and Master's thesis projects. Next to the PhD research and teaching activities, he was part of various other research projects on topics including organizational transformation, mission governance, circular change programmes, and platform ecosystems. Moreover, he was invited to partake in the research assessment committee for the Faculty of Architecture at the Delft University of Technology and was part of the organizing committee of the Eu-SPRI 2024 conference.

During his PhD research, Tom presented his research findings to practice on several occasions, including a technical briefing in the Netherlands' House of Representatives. He continued his academic career as an Assistant Professor at the University of Twente as of February 2024, in which he remains working on circularity and transitions in the context of civil engineering and construction management.

Circularity has become a central approach to making the infrastructure sector more future-proof. As such, circularity is positioned as a transformative mission. However, the socio-technical transition required to achieve this mission is steeped with complexity, uncertainty, and contestation which makes its governance a tricky task.

This PhD dissertation delves into the systemic barriers to the mission-oriented transition and offers various ways to deal with those on a sectoral, organizational, and inter-organizational level. In doing so, this dissertation aims to provide scholars and practitioners with the tools to effectively steer and support the transition towards a circular infrastructure sector.