*Master's Thesis – Master Sustainable Business and Innovation*

# Mission-oriented Innovation System (MIS) analysis on circular water authorities in 2050

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# Abstract

This thesis was conducted in collaboration between Utrecht University (UU) and Hoogheemraadschap de Stichtse Rijnlanden (HDSR), and is built up as follows:

The *Introduction* discusses why the circular economy is deemed important for the transition towards a sustainable future. Recently, the regional water authorities in the Netherlands created a mission to transition towards operating completely circular by 2050. This research aims to aid this transition by analyzing how innovative solution pathways can develop and diffuse more rapidly to achieve swift mission success.

The *Theory* section discusses how grand societal challenges have taken the forefront in policy discourse. To tackle these challenges, a proper understanding of innovation dynamics is vital. However, existing approaches (NSI, SIS, TIS) are deemed inadequate to analyze the 'wicked' nature of grand societal challenges. The 'Mission-oriented Innovation System' (MIS) is a recently developed approach that is specifically tailored to the dynamics of these challenges.

The *Methodology* section provides a detailed description of the five stages of the research process. First, the relevant problems and solutions related to the mission were analyzed. Second, the actors, networks, institutions, and materiality that shape the MIS were identified. Third, nine system functions were examined through 23 interviews with MIS actors. Fourth, weakly fulfilled system functions were analyzed in more detail to identify barriers. Fifth, this research reflected on (planned) governance actions to assess whether barriers were addressed.

The *Results* section provides a detailed description of the insights of all five research stages. To summarize, the third stage revealed that all nine system functions contained severe weaknesses. The fourth stage displayed that most of these weaknesses were interconnected. The fifth stage indicated that while existing governance actions address several barriers, many were only partly addressed or neglected. Nine recommendations were made to address these 'blindspots'.

The *Discussion* provides valuable insights for further development of MIS theory. First, this research introduced the concept of 'sub-innovation systems', which lead to a more intricate assessment of the MIS. Second, it showed how the concept of 'system building' is valuable for understanding the role of influential actors in the MIS structure and functioning.

The *Conclusion* provides an answer to the main research question. It concludes that by implementing the recommended governance actions to address blind spots in current/planned policy, innovative solution pathways will be able to develop and diffuse more rapidly to achieve 100% circular regional water authorities in 2050.

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# 1. Introduction

In recent decades, grand societal challenges have taken the forefront in (inter)national policy discourse (Boon & Edler, 2018; Fagerberg & Hutschenreiter, 2019). Well-known examples of these challenges are climate change and concerns regarding health & wellbeing. According to Mazzucato (2018a, p. 803), these challenges are characterized by their 'wickedness', "*in the sense that they are complex, systemic, interconnected, and urgent, requiring insights from many perspectives".* Tackling these grand societal challenges is important for human and environmental wellbeing in the upcoming years and for future generations (Kwakkel & Pruyt, 2015).

Innovation plays an essential role in tackling these challenges by providing potential solution pathways (Hekkert et al., 2020). Attempts can be made at steering the direction of innovation in order to make an effective transition possible (Mazzucato, 2017). 'Transformative Innovation Policy' and 'Mission-oriented Innovation Policy' have been prompted as effective methods (Diercks et al., 2019; Wanzenböck et al., 2020). Although there are some differences, these policy interventions share a similarity in their aim to overcome grand societal challenges (Van der Loos et al., 2020).

Tackling grand societal challenges through policy intervention starts with a proper understanding of innovation dynamics (Kattel & Mazzucato, 2018). 'Systems perspectives' are a beneficial method for a rigorous understanding (Kuhlman et al., 2010). Over the years, several different systems perspectives have been introduced to analyze innovation dynamics, such as national-, sectoral- or technology-specific innovation systems (Hekkert et al., 2007). However, several authors argue that the current perspectives are not adequate frameworks in order to comprehend innovation dynamics related to grand societal challenges (Haddad & Bergek, 2020; Hekkert et al., 2020; Ghazinoory et al., 2020).

Within the systems perspectives literature, the Mission-oriented Innovation System (MIS) has emerged as a promising framework to understand grand societal challenges. In contrast to other systems perspectives, this framework is tailor-made to analyze grand societal challenges and, specifically, the directionality provided by missions (Hekkert et al., 2020). Conducting a MIS analysis helps to understand the strengths and weaknesses of innovation systems bound by a mission. Understanding these weaknesses and targeting their underlying barriers/ root causes with governance actions helps to make a transition go more swiftly to tackle the societal challenge (Wesseling & Meijerhof, 2021).

The circular economy is an interesting case in terms of grand societal challenges. The concept has gained a lot of traction in the past few years and is indicated as an important part of the transition towards a sustainable future (Geissdoerfer et al., 2017). Circularity is not a grand societal challenge on its own. Instead, it is an overarching solution for two other challenges: climate change and resource depletion (Murray et al., 2017). In 2015, the European Commission created an EU action plan for a circular economy. According to this plan, this effort is necessary to *"develop a sustainable, low carbon, resource efficient and competitive economy"* (European Commission, 2015, p. 2).

The Dutch government responded to this call to action with a national program to transition towards a circular economy. In this program, it is explicitly stated that it is the goal of the government to develop a completely circular economy by 2050 (Ministerie van Infrastructuur en Milieu & Ministerie van Economische Zaken, 2016). In 2017, the "Resource-agreement" (*Grondstoffenakkoord*) was recorded, in which all undersigned parties agreed to support developing a completely circular economy by 2050 in the Netherlands (Rijksoverheid, 2017). This agreement was also signed by the

Dutch Water Authorities (*Unie van Waterschappen*) on behalf of the 21 regional water authorities (*waterschappen of hoogheemraadschappen*) (Unie van Waterschappen, 2018).

Regional water authorities in the Netherlands are governmental organizations responsible for managing wastewater treatment, flood defenses, and regulating water levels. Despite the relatively new ambition to contribute towards a 100% circular economy, the regional water authorities and affiliated parties have identified more than 30 different innovations which can be used as solution pathways. However, the innovation policy has not yet been optimized to 'shape' innovation and tackle this challenge swiftly (Royal HaskoningDHV, 2020; Roest et al., 2020).

Although MIS is a potentially promising framework to support policymakers, it only emerged recently and is still underdeveloped (Janssen et al., 2020). Based on a review of the few existing published works regarding MIS, three gaps in literature have been identified. First, up until now, there has only been one working paper that conducted a MIS analysis (Wesseling & Meijerhof, 2021). Therefore, there is an urgent need for more deductive research in which the MIS framework is applied. This research adds to the body of knowledge regarding MIS by testing it in a distinct case. Secondly, there is an insufficient understanding of how MIS dynamics work in missions with influential organizations as the central focus. Third, missions have been broken down into multiple smaller missions in the past to make them more actionable. However, there is a lack of knowledge on how this affects the analysis of the smaller, interconnected innovation systems.

This research addresses the above-mentioned gaps by applying the MIS framework to the transition towards 100% circular water authorities by 2050. Thereby answering the research question:

<u>How can innovative solution pathways develop and diffuse more rapidly in order to make Dutch regional water authorities operate completely circular in 2050?</u>

This research adds relevant scientific knowledge to the growing body of MIS literature. First, it tests the MIS framework in a completely new case. This opens new research pathways by providing insights on understudied components of MIS theory, such as the fulfillment of solution directionality. Secondly, it adds to the understanding of how to analyze organization-centered missions by using the 'system builder' concept. Third, it provides a new dimension to MIS analysis through the concept of 'sub-innovation systems'. A more intricate assessment can be made on the overarching MIS by analyzing how these sub-systems are build up and function. Additionally, it opens the ability to compare/ learn from sub-systems.

This research bears societal relevance by supporting a swift transition towards a circular economy to tackle the affiliated grand societal challenges. It supports the identification of barriers that hinder the development and diffusion of innovation from reaching 100% circular regional water authorities in the Netherlands. The Dutch Water Authorities, several regional water authorities, and research institute KWR have explicitly stated their interest in this research topic, showing that this research is widely supported. MIS actors can use these identified barriers to create governance actions to address the root causes that prevent swift mission success. Furthermore, this research contains an assessment of current/planned policy and provides recommendations for complementary governance actions.

# 2. Theory

The leading underlying theory used in this research is the 'Mission-oriented Innovation System' (MIS). This theory was mainly used in a deductive manner. MIS was developed recently and is only used once in a scientific article (Wesseling & Meijerhof, 2021). Therefore, there is an urgent need to test the theory. However, since the theory is novel and every mission is unique (Janssen et al., 2020; Wittmann et al., 2020), some alterations to the theory are necessary. Therefore, the research also includes an inductive component, as it contributes to the existing theory.

To understand the theory regarding MIS, it is essential to give some background information on Transformative Innovation Policy (TIP)/ Mission-oriented Innovation Policy (MIP) and the Innovation System (IS) approach. For a complete overview of all concepts (and their definitions) mentioned in Chapter 2, see Appendix A.

## 2.1 TIP/MIP

As mentioned in the introduction, there is an important role for innovation in tackling grand societal challenges (Hekkert et al., 2020). Innovation policy makes an attempt at shaping the direction of innovation, which is necessary to achieve transformational change (Mazzucato, 2016).

In recent years, innovation policy has transformed in order to be better equipped towards dealing with increasingly important grand societal challenges (Diercks et al., 2019). This new generation is described as "Transformative Innovation Policy" (TIP) and "Mission-oriented Innovation Policy" (MIP). Although similar in many aspects, MIP distinguishes itself through more attention to clear and measurable goals or 'missions' (Haddad et al., 2019). A mission can be defined as *"an urgent strategic goal that requires transformative systems change directed towards overcoming a wicked societal problem."* (Hekkert et al., 2020, p. 76).

Although MIP is gaining traction among policymakers, there still seems to be a struggle in the implementation. Policy departments lack the ability to properly evaluate innovation dynamics in order to shape their direction (Hekkert et al., 2020; Kattel & Mazzucato, 2018). 'Innovation Systems' (IS) is considered as a valuable method to create a comprehensive understanding of relevant innovation dynamics (Kuhlman et al., 2010).

## 2.2 Innovation System (IS) approach

'Innovation systems' is a concept that is prevalent in the innovation sciences and transition communities and is used to analyze innovation dynamics (Hekkert et al., 2007; Jacobsson & Bergek, 2011). The concept is built on the core principle that the development and diffusion of innovation is a collective activity (Hekkert et al., 2007; Bergek et al., 2008). This means that innovation takes place in an 'ecosystem' of multiple contributing actors. This 'ecosystem' is commonly referred to as the 'innovation system' and can be defined as *"the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify, and diffuse new technologies"* (Freeman, 1987, p. 1).

The reason for studying innovation systems is that "*the success of innovations is to a large extent determined by how the innovation system is build up and how it functions*" (Hekkert et al., 2011, p. 3). An analysis of an innovation system allows understanding why some innovations succeed while others fail. By making alterations to existing innovation systems, the IS approach supports successful development and diffusion of innovation (Bergek et al., 2008).

Over the years, several different systems perspectives have been introduced to analyze innovation dynamics. Some of these perspectives are related to a geographical unit or industry, such as the National Systems of Innovation (NSI) and Sectoral Innovation System (SIS), respectively (Lundvall, 2010; Breschi & Malerba, 1997). The Technological Innovation System (TIS) perspective puts a specific technology at the center of the analysis (Bergek et al., 2015; Carlsson & Stankiewicz, 1991). Several authors argue that the current system perspectives are not adequate frameworks to comprehend innovation dynamics related to grand societal challenges (Haddad & Bergek, 2020; Hekkert et al., 2020; Ghazinoory et al., 2020).

## 2.3 Mission-oriented Innovation System (MIS)

Within the systems perspectives literature, the Mission-oriented Innovation System (MIS) has emerged as a promising framework to understand grand societal challenges. MIS can be described 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). Recently, Wesseling & Meijerhof (2021) created a structural-functional approach for MIS analysis based on the existing framework for studying TIS (Hekkert et al., 2007; Bergek et al., 2008). The approach consists of 5 consecutive stages:

*1. Problem-Solution diagnosis*

In this stage, the mission is analyzed regarding its overarching grand societal problem(s) and possible solutions. There are two essential concepts within this stage. The first is 'problem directionality', which consists of *“the way in which different societal problems are included and prioritized in the mission formulation”* (Wesseling & Meijerhof, 2021, p. 6). Analyzing the included societal problems leads to a better understanding of the underlying drivers and complexity of the mission. The second concept is 'solution directionality', which *“refers to the factors that determine how stakeholders search for and invest in the solutions they deem promising for fulfilling the mission.”* (Wesseling & Meijerhof, 2021, p. 6). Understanding the identification and prioritization of solutions creates a comprehensive overview of how actors, at this point, (expect to) tackle the mission. In contrast to TIS analysis, a MIS consists of both social and technological innovations, as both types of solutions are necessary to tackle grand societal challenges (Hekkert et al., 2020; Kattel & Mazzucato, 2018).

*2. Structural analysis*

During the second stage, similar to a TIS analysis, the structural components of the innovation system are identified. These components consist of actors, institutions, networks, and materiality, which play a role in the development, diffusion, and implementation of innovations (Wanzenböck et al., 2020; Hekkert et al., 2011). An important concept within this stage is 'mission arena'. It can be defined as *“the actors that are engaged in the highly political and often heavily contested process of mission governance (. . .) [by] providing direction to the MIS as well as mobilizing and aligning existing innovation system structures into a semi-coherent ensemble that aims to pursue the mission.”* (Wesseling & Meijerhof, 2021, p. 7; Loorbach, 2010). Distinguishing the mission arena from the overall MIS helps to identify which actors are essential in directing and mobilizing the MIS.

*3. System functions (SFs)*

In the third stage, 'system functions' are analyzed, which *"refers to ‘what is achieved in the system’ in terms of processes that have a more direct and immediate impact on the ‘goal’ of the system"* (Bergek et al., 2010, p. 8, 9). According to Johnson (1998, p. 16), *"the concept of function may be used as a tool to describe the present state of a system"*. The system function analysis gives a comprehensive insight into the current state (or 'functioning') of the innovation system. In Table 1, all MIS system functions are mentioned, with a concise description of what every system function entails. Most system functions in a MIS analysis bear a resemblance to the ones in a TIS analysis. However, there is one considerably different function. The original TIS analysis contained the function 'Guidance of the

Search', referring to the clarity of the vision regarding industry/market development (Hekkert et al., 2011). The MIS analysis replaced this function with 'Providing Directionality', as this better encompasses the *"interrelatedness of solutions"*, which *"requires (. . .) processes of solution coordination in solution pathways that are overlooked in a TIS analysis".* Additionally, *"the TIS functions also do not capture well the mission arena's continued, reflexive governance processes".* Therefore, 'Providing Directionality' consists of 'problem directionality', 'solution directionality', and 'reflexive governance' (Wesseling & Meijerhof, 2021, p. 13; Weber & Rohracher, 2012).

Table 1: description of system functions, tailored to the MIS analysis. Based on the work of Wesseling & Meijerhof (2021), Hekkert et al. (2007), Hekkert et al. (2011) and Bergek et al. (2010)

| **System Function** | **Description** |
|---|---|
| SF1: Entrepreneurial activities | Experiments with uncertain outcomes (risk) through: e.g. developing new and existing solutions, entering new markets and innovating business models. |
| SF2: Knowledge development | The development of knowledge through 'learning by doing' and 'learning by searching'. The developed knowledge leads to a better understanding of the societal problem and the solution pathways. |
| SF3: Knowledge diffusion | The exchange of information in networks containing knowledge regarding relevant societal problems and solution pathways through different media, e.g. reports, conferences, workshops, etc. |
| SF4: Providing directionality<br><br>4A: Problem directionality | <br><br><br>*"The direction provided to stakeholders' societal problem conceptions and the level of priority they give it."* (Wesseling & Meijerhof, 2021, p. 11) |
| 4B: Solution directionality | *"The direction given, both by existing system structures and the mission arena, to the search for new and further development of existing technological and social solutions, as well as the coordination efforts needed to identify, select, and exploit synergetic sets of solutions to the mission."* (Wesseling & Meijerhof, 2021, p. 11) |
| 4C: Reflexive Governance | *"Reflexive deliberation, monitoring, anticipation, evaluation and impact assessment procedures; these provide the analytical and forward-looking basis for redirecting the system's problem framing and search for solutions based on lessons learned and changing context. Reflexive governance can be seen as second-order directionality, and it can be initiated by the mission arena or by critical outsiders."* (Wesseling & Meijerhof, 2021, p. 12) |
| SF5: Market Formation & Destabilization | Creation of niche markets or favourable tax regimes to protect new solutions during development and diffusion; Support for innovation scale-up; Phase-out current practices and/or technologies that could negatively influence the mission. |
| SF6: Resource (re)allocation | Allocation of sufficient resources (human, financial and physical) to support all key activities/functions of the innovation system. |
| SF7: Creation and Withdrawal of legitimacy | Counteract resistance to change and create legitimacy through (vocal) support by stakeholder groups, the public and other actors. Acceptance and compliance by relevant institutions. This should lead to: (1) prioritization of the underlying problems of the mission, and support for solution pathways, and (2) withdrawal of legitimacy for practices harmful to mission success. |

*4. Systemic barriers analysis*
In the fourth stage, the weak or negatively fulfilled system functions are analyzed in more detail. This stage of the analysis aims to understand the systemic barriers behind the weak fulfillment of functions and explore the underlying root causes. Additionally, interdependent systemic problems are analyzed to identify potential system lock-in (Wesseling & Meijerhof, 2021; Wesseling & Van der Vooren, 2017).

*5. Reflection on (planned) governance actions*
Hekkert et al. (2007, p. 414) argue that *"if we knew what kind of activities foster or hamper innovation–thus, how innovation systems 'function'–we would be able to intentionally shape innovation processes."*. The final stage of the MIS analysis consists of identifying governance actions that are/ can be used to address the systemic barriers mentioned in stage 4. These governance actions should support the innovation system in tackling the root causes of the systemic barriers. According to Wesseling & Meijerhof (2021), the instruments can be analyzed 'ex-ante' as a *"formative evaluation of the mission governance actions"* or 'ex-post' as a *"summative mission evaluation tool"* (p. 14). Additionally, the instruments can be analyzed *during* the mission progress, *"stressing that the MIS is already engaging in various innovation activities and that the mix of actions should focus on resolving the remaining MIS barriers in order to effectively and efficiently boost the performance of the MIS."* This assesses whether the current/planned governance actions are suitable to address existing barriers (Wesseling & Meijerhof, 2021, p. 14). Ultimately, this should lead to an increase in the pace of transition, to make the mission a success.

As mentioned in the introduction, this research aims to understand how innovative solution pathways can develop and diffuse more rapidly to achieve its mission. MIS is an appropriate theory for several reasons, as it addresses the main issues regarding innovation policy for grand societal challenges (see table 2).

Table 2: summary of how MIS analysis addresses issues regarding innovation policy for a grand societal challenge

| **Issues regarding innovation policy for grand societal challenges** | **How MIS analysis addresses these issues** |
|---|---|
| Policymakers lack necessary understanding of innovation dynamics (Hekkert et al., 2020) | MIS analysis is built on Innovation Systems analysis, a proven method to understand development and diffusion of innovations (Kuhlmann et al., 2010) |
| Many innovation system perspectives (TIS, SIS, etc.) are not adequate for analysing innovation systems regarding grand societal challenges as it does not take its characteristics into account (Haddad & Bergek, 2020; Hekkert et al., 2020; Ghazinoory et al., 2020). | MIS analysis is tailor made for grand societal challenges:<br>1. it puts the mission at the centre of the analysis, instead of a geographical scope or technology (Hekkert et al., 2020)<br>2. it takes the temporal, multidisciplinary and international nature of grand societal challenges (Daimer et al., 2014) into account by being temporal and embedded in other innovation systems (TIS, SIS, etc.) (Wesseling & Meijerhof, 2021)<br>3. in contrast to TIS, MIS analyses *both* technological and social innovations, as grand societal challenges cannot be tackled by just one type of solution (Kattel & Mazzucato, 2018). |

## 2.4 Contribution to theory
This research makes two contributions to theory. First, it bridges MIS and 'System Building' literature through organization-centered missions. Second, it describes how 'sub-innovation systems' could provide a helpful approach for analyzing a MIS.

### 2.4.1 Organization-centered MIS & System Building

MIS literature states that every mission is unique (e.g., Mazzucato, 2018a; Wittmann et al., 2020). According to Hekkert et al. (2020, p. 77), missions can be *"tied to a generic societal function (e.g. sustainable mobility), ( . . . ) cover multiple societal functions (e.g. achieving a 100% circular economy) or focus on highly specific challenges (e.g. achieving long-term survival for the majority of cancer patients by 2030)."*. Even within these three types of missions, there are unique dimensions. Recently, Dutch governmental policymakers have initiated missions that cover multiple societal functions, with a remarkable twist. These missions were posed with an influential organization as a centralized part of the mission. Examples are: 'Rijkswaterstaat 100% energy neutral in 2030', and '100% circular regional water authorities in 2050' (Rijkswaterstaat, 2021; Nanninga & Glas, 2021).

While organizations have posed their own sustainability goals (e.g., cleaner production, pollution prevention) for many years (Vermeulen & Witjes, 2016), these are not identical to the recent organization-centered missions. Due to their *"complex and often wicked nature, ( . . . ) missions cannot be solved by one actor—be it politics, science, industry or civil society—alone."* (Jütting, 2020, p. 2). Although these missions are centered around a (type of) organization, multiple actors make a necessary contribution to developing and diffusing solutions to achieve mission success (Hekkert et al., 2020), and therefore must be analyzed through MIS dynamics.

Innovation systems in which an influential organization or actor takes center stage relate to the scientific concept of 'system building', which gained traction in TIS literature (Musiolik et al., 2020). System building is described as *"the deliberate creation or modification of broader institutional or organizational structures (system resources) in a technological innovation system carried out by innovating actors."* (Musiolik et al., 2012, p. 1035). Kukk et al. (2016, p. 1560) state that this concept *"offers valuable insights from an actor-oriented perspective on creating innovation systems by analyzing the role and transformative capacity of specific actors as system builders."* This makes the concept a valuable addition to MIS to understand the role of influential organizations on how the system is build up and functions.

Although multiple researchers have used 'system building' for TIS analysis, the concept has not been used in a MIS context. Actors that create a mission in which they have a critical role could be identified as 'MIS system builders'. They are taking part in 'system building' activities by establishing a well-functioning innovation system (Negro et al., 2012). The addition of the 'system building' concept to MIS theory offers insight into how actors exert influence on innovation systems, which is still an understudied dynamic (Kukk et al. 2016, Musiolik et al., 2020).

Wesseling & Meijerhof (2021, p. 22) argues that *"systematically comparing ( . . . ) missions and the MIS dynamics and challenges that they present would be a fruitful way of theory building on how different missions and mission arenas impact MIS dynamics."*. Therefore, this research makes a scientific contribution by analyzing the MIS dynamics of missions in which an influential organization (i.e., a system builder) is the central focus.

### 2.4.2 Sub-Innovation Systems

A significant hurdle for analyzing a MIS that covers multiple societal functions/sectors is the enormous scope. Hekkert et al. (2020) give the example of a mission posed by the Dutch Ministry of Economic Affairs and Climate: *"The reduction of national greenhouse gas emissions by 49% by 2030, with the outlook of 95% by 2050 compared to 1990 emission levels"* (translated from Dutch) (Ministerie van Economische Zaken en Klimaat, 2019, p. 5). This mission was broken down into multiple smaller targets per sector (e.g., built environment, agriculture, mobility). By breaking down a mission into smaller sub-categories, the scope becomes more actionable (Mazzucato, 2018b). Nonetheless, all these smaller sectoral missions contribute to the achievement of the national mission.

Inherent to the process of breaking down a mission, the innovation system is also broken down into smaller systems. These innovation systems can be analyzed as multiple stand-alone sectoral MIS analyses (e.g., the case study by Wesseling & Meijerhof (2021), which analyzed the mission related to the reduction of greenhouse gas emissions in the Dutch maritime short sea shipping sector).

However, a case can be made for breaking down innovation systems into smaller systems while still holding on to their interrelated nature. These smaller, interrelated systems can be deemed as *'sub-innovation systems'* (based on the notion of 'sub-systems' used in the IS-analysis by Carlsson et al. (2002) and the RIS-analysis by Cooke (2008)). Up until now, no definition has been provided for this concept. Therefore, stipulative definitions will be used throughout this research. 'Sub-innovation systems' can be defined as *"a set of mission-oriented innovation systems that each aim to complete a unique societal mission, while being interconnected through an overarching MIS.".* Likewise, an 'overarching MIS' can be defined as *"a mission-oriented innovation system that is dependent on the achievement of multiple smaller missions in order to complete its mission."*

These dynamics between the overarching MIS and the sub-systems are visualized in Figure 1. The overarching MIS (large black circle) is broken down into multiple smaller 'sub-innovation systems' (smaller blue, green & orange circles). These 'sub-systems' contribute to the achievement of the overarching goal (i.e., the overarching mission). Each sub-system has unique attributes while still being interrelated. They are interrelated in the sense that they share multiple structural components, such as actors, networks, and innovations (represented in Figure 1 with the letter 'A'). However, each sub-system also has its unique actors, materiality, innovations, etc., that are only relevant to the achievement of said sub-system (represented in Figure 1 with the letter 'C'). A hybrid variant is also possible, in which some sub-systems share similar components, but not all sub-systems (represented in Figure 1 with the letter 'B').

Using sub-innovation systems has several benefits over creating multiple stand-alone MIS analyses. First, it recognizes that there is an interrelatedness between the different MIS analyses. All sub-systems work towards achieving a higher goal (i.e., the over-arching mission). The sub-systems are interrelated through similar actors, networks, solution pathways, etc. Second, it opens the ability to compare/ learn from sub-systems with more ease. Under normal circumstances, comparing missions and learning from them can be challenging. Ständer (2019, p. 10) argues: *"missions are context-specific and cannot be easily translated into best-practice guidance. An effective mission-oriented policy might only function in the specific system for which it was designed. This makes it hard to copy a successful mission from another country, societal challenge or period."* However, due to the relatively similar context, the similarities and differences in strengths, weaknesses, and barriers in the sub-systems can be evaluated and learned from.

Using sub-innovation systems also has several benefits over conducting a MIS analysis that covers a cross-sectoral mission that is not broken down into smaller missions. First, it recognizes that, in order to achieve the mission, multiple smaller missions must be achieved first. Second, it identifies that each sub-system has a unique goal and output, which affects the way the sub-system is build up and functions. Third, the sub-system approach ensures that all relevant smaller missions are represented equally in the analysis. Fourth, this approach opens the opportunity to analyze if potential tensions between the sub-systems hamper the completion of the overarching mission.

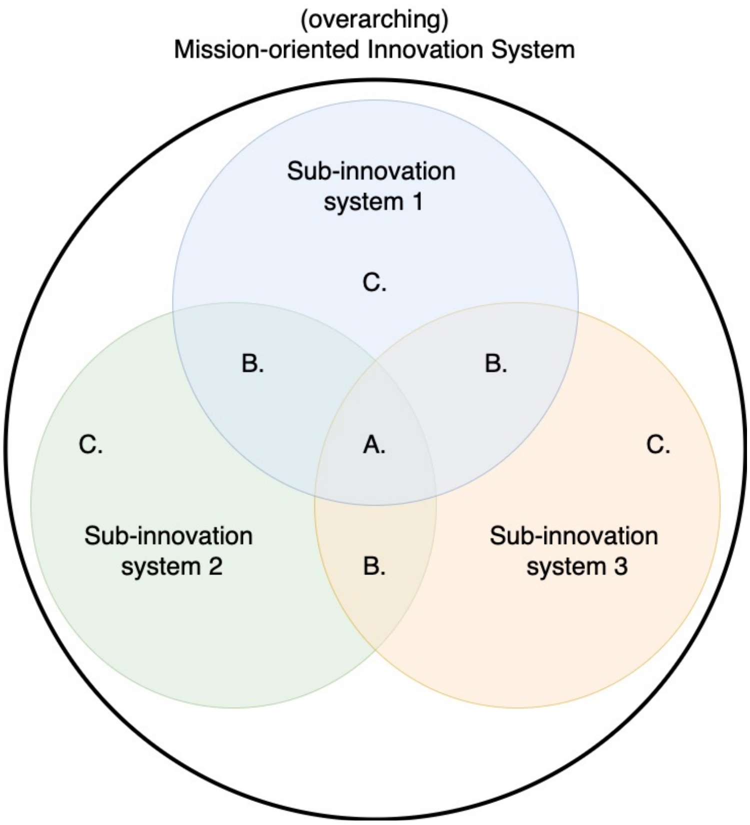


Figure 1: Visual representation of 'sub-innovation system' dynamics in a MIS

### 2.4.3 Contributions to theory in relation to the case study

The case study that is used in this research overlaps both theoretical contributions. The mission '100% circular regional water authorities in 2050' both consist of an organization-centered mission and can be broken down into multiple interrelated sub-innovation systems. This will be elaborated on in the Methodology section.

The MIS theory benefits from these contributions in several ways. First, it adds to the understanding of MIS-dynamics related to the achievement of an organization-focused mission. Building on this contribution, it connects emerging MIS theory with system building literature. Second, it explains how the concept of 'sub-innovation systems' can be a valuable tool to analyze larger missions that contain multiple societal functions/sectors. Furthermore, it uses a case study as an example to show how to incorporate sub-systems in the recently developed approach for MIS analysis.

This contribution impacts multiple aspects of the structural-functional approach. First, it impacts the Problem-Solution diagnosis and Structural analysis, as the system builder and sub-innovation systems are an essential aspect of how the MIS is structured. Each sub-system has unique problems, solutions, and systemic components that need to be identified. The 'system builder' concept supports an intricate understanding of how influential organizations affect how the innovation system is build up. Secondly, it impacts the System Functions analysis, as certain SF weaknesses will be (1) specific for certain sub-systems and/or (2) related to the actions of the system builder. These additions will be explained in more detail in the 'Methodology' section.

# 3. Methodology

## 3.1 Case Description

The MIS framework is applied in a case study concerning the transition towards '100% circular regional water authorities in 2050'. This section consists of a brief case description of the circular economy, missions, and the regional water authorities.

### 3.1.1 Circular economy (missions)

Circular Economy (CE) is a concept which gained traction since the late 1970s and has been influenced over the years by many sustainability concepts, such as 'cradle-to-cradle', 'regenerative design', and 'industrial ecology'. Policymakers, academics, and businesses have posed the concept as a promising way to achieve sustainable development (Geissdoerfer et al., 2017; Bauwens et al., 2020). CE can be defined as *"an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations."* (Kirchherr et al., 2017, p. 224-225).

This definition shows that CE has two specific characteristics relevant to MIS analysis. First, there is a multitude of methods by which 'end-of-life' can be replaced. These methods are all related to the concept of *"value retention processes"*, which are *"mechanisms to retain value in our economy"* (Haupt & Hellweg, 2019, p. 1). Reike et al. (2018) tried to create a typology for value retention processes, which consists of 10 Retention Options (RO's): Refuse (R0), Reduce (R1), Re-sell/Re-use (R2), Repair (R3), Re-furbish (R4), Re-manufacture (R5), Re-purpose (R6), Recycle (R7), Recover (energy) (R8) and Re-mine (R9). According to this framework, R0-R2 are identified as 'client/user choices', R3-R5 are forms of 'product upgrades', and R6-R9 is considered as 'downcycling'. Second, this definition shows that 'circularity' is not an end goal. Instead, it aims for sustainable development, as it tries to *"decouple prosperity from resource consumption (. . .) and thus ensure closed loops that will prevent the eventual disposal of consumed goods in landfill sites."* (Sauvé et al., 2016, p. 53). CE is deemed a promising method to transition towards a sustainable way of living as it addresses multiple societal problems, e.g., resource depletion, climate change, and job availability (Murray et al., 2017; European Commission, 2015).

In the past 20 years, CE has become more recognized in policymaking and has influenced (inter)governmental strategies worldwide (Geissdoerfer et al., 2017). Recently, MIP and MIS literature have identified the CE as an important target for missions (Jütting, 2020; Wittmann et al., 2020; Hekkert et al., 2020).

However, one notable remark is that the concept of CE is still contested. Despite good intentions, several paradoxes have been identified that hamper CE as a tool for completing sustainability goals (Greer et al., 2021). Examples are: (1) the 'circular economy rebound', in which a CE backfires by *"increasing overall production and use of products and therefore environmental impact."* (Zink & Geyer, 2017, p. 595). (2) Sustainability trade-offs, which are *"situations characterized by conflicts between the desired objectives, where it is impossible to satisfy all criteria simultaneously."* (Kravchenko et al., 2021, p. 1). The mention of these paradoxes/ trade-offs is not meant to take away from the legitimacy of CE as a promising concept. However, these factors are essential to consider while evaluating a CE-related MIS, as working towards mission success can be in contestation with other sustainable ambitions and even the end-goal itself (i.e., achieving sustainability). These issues are directly related to MIS-concepts such as 'Problem-Solution diagnosis' and 'problem directionality' (SF4A) and were considered in the methodology & results of this research.

### 3.1.2 Mission '100% circular regional water authorities in 2050'

Regional water authorities in the Netherlands are decentralized governments, like provinces and municipalities. These organizations have a long history in this country, as water management has been prevalent for almost 900 years. The Netherlands consists of 21 regional water authorities in total (HDSR, 2018; ProDemos, 2021a, 2021b).

In 2017, the '*Grondstoffenakkoo*rd' (Resource-agreement) was recorded. Numerous governmental organizations and firms are committed to supporting the development of a completely circular economy by 2050 in the Netherlands (Rijksoverheid, 2017). The regional water authorities were among the signatories and posed the mission: '100% circular regional water authorities in 2050' (Nanninga & Glas, 2021).

There are two distinct features of how regional water authorities operate that impact how this mission is handled. First, it is important to note is that water authorities are managerial organizations (*beheer- en onderhoudsorganisaties*), which inclines that the execution of their operation is primarily outsourced to different (non-governmental) actors (PIANOo, 2021; Hoogheemraadschap van Delfland, 2015). This has the significant implication that water authorities are dependent on other contributing actors to achieve the mission (i.e., an innovation system). Regional water authorities can be identified as 'MIS system builders' as they take part in establishing a well-functioning innovation system in order to achieve their organization-specific mission (Negro et al., 2012).

Secondly, each authority is responsible for three 'core' activities (*kerntaken*) in their region:

1. <u>The treatment of wastewater.</u> Water authorities are responsible for protecting the water quality in ditches, lakes, streams, rivers, etc. Water used by citizens/organizations is transported through a sewage system towards wastewater treatment plants, where the wastewater is purified. The purified water (effluent) is then discharged into a river or canal. This effluent is not drinkable (as it still contains some contaminants) but meets specific water quality standards. Relevant tasks within this 'core activity' are: (1) pre-treatment of wastewater, (2) biological purification, (3) processing sewage sludge, and (4) inspection & maintenance of wastewater treatment plants. (Unie van Waterschappen, 2021a; HDSR, 2021a)

2. <u>Maintenance and control of flood defenses.</u> The Netherlands is under constant threat of potential flooding due to its geographical characteristics as a delta and its location below sea level. Water authorities protect the Netherlands against flooding. This is achieved through the management of approximately 18.000 km of dikes. Relevant tasks within this 'core activity' are: (1) inspection and maintenance of flood defenses (e.g., dikes and dunes), (2) muskrat control, (3) relocating dikes (*ruimte voor de rivier*), and (4) coastal reinforcement. (Ministerie van Infrastructuur & Milieu, 2015; Unie van Waterschappen, 2021b)

3. <u>Regulating water levels.</u> Water authorities adjust the water levels, e.g., by draining water during heavy rainfalls and storing water during droughts. These activities are relevant for preserving multiple societal functions, such as agricultural activity, economic stability, recreation, residence, and nature conservation. Relevant tasks within this 'core activity' are: (1) dredging waterways, (2) removing biomass in and around waterways, and (3) maintenance and control of pumping stations. (Unie van Waterschappen, 2021c, 2021d; HDSR, 2021b)

These core activities are both unique and interrelated at the same time. Each core activity can be seen as its own domain. All three activities have their own unique outputs & challenges and consist of distinct actors, networks, assets, and technologies. However, they are interrelated through multiple different networks and actors (water authorities, among others) that are active in all/ a combination of these domains.

Based on this notion, in order to achieve the over-arching mission '100% circular water authorities in 2050', three smaller missions must be achieved:

- 100% circular wastewater treatment in 2050
- 100% circular flood defenses in 2050
- 100% circular water level management in 2050

These smaller missions can be analyzed through three separated MIS analyses. However, as explained in chapter 2.4.2, the concept of 'sub-innovation systems' provides a more suitable approach. Recognizing their unique- and interrelated elements opens the ability to (1) compare the sub-systems and (2) understand the dynamics of their mutual relationships. Furthermore, by analyzing how these sub-systems are build up and function, a more detailed assessment can be made on the functioning of the overarching MIS.

From here on, the three sub-innovation systems are abbreviated as 'Wastewater Treatment', 'Flood Defenses', and 'Water Level'.

## 3.2 Sub-questions

As mentioned in the Theory section, the MIS analysis consists of five stages. This section elaborates on the methodological choices per stage in order to realize the research goal. The research question was broken down into several sub-questions, based on the structural-functional approach and diagnostic questions by Wesseling & Meijerhof (2021). Table 3 shows which sub-questions will be answered per stage of analysis. As part of the theoretical contribution, this methodology shows how the interconnections and unique differences between the sub-innovation systems were identified during the analysis (in the Problem-Solution diagnosis, Structural Analysis & System Functions).

Table 3: Sub-questions per stage of MIS analysis, based on the structural-functional approach and diagnostic questions of Wesseling & Meijerhof (2021)

| **Stage of MIS analysis** | **Sub-questions** |
|---|---|
| Problem-Solution diagnosis | *1. How do different societal problems and 'wants' relate to the mission?*<br>*2. What technological- and social solutions are relevant to the mission?* |
| Structural Analysis | *3. What actors are involved in:*<br>*A. setting up the mission arena?*<br>*B. the mission formulation?*<br>*C. mobilizing MIS components through governance actions?*<br>*D. the reflexive governance of the mission?*<br>*4. What actors, networks, institutions and materiality support the development and diffusion of the mission's solution, including the phase-out of harmful goods and practices?* |
| System Functions | *5. What are the weakly fulfilled system functions within the MIS?* |
| Systemic Barriers analysis | *6. What are the underlying root causes for these weak system functions?* |
| Reflection on (planned) governance actions | *7. Are the existing governance actions addressing the (root causes of) identified barriers and are complementary governance actions necessary?* |

## 3.3 Problem-Solution diagnosis

In this stage of the MIS analysis, sub-questions 1 and 2 were answered.

In order to identify the related societal problems and 'wants', desk research & expert consultation were used. As mentioned in the case description, CE is a tool to solve societal problems, but it can also have adverse effects in practice. Therefore, this section is divided into two parts. First, the problems related to the mission 'formulation' are discussed (i.e., the societal problems that CE addresses). Second, the problems related to 'execution' are discussed (i.e., the societal problems that compete with CE for priority).

For the mission 'formulation', policy documents about the transition towards a CE were analyzed. These documents include the reasoning for the transition towards CE and which societal problems and wants should be tackled in the process. These policy documents were analyzed on three levels. First, on a European level, as the European Union is commonly seen as a pioneer in the large-scale implementation of CE and the reason why European countries started to follow suit (Mhatre et al., 2020). Second, on a national scale, to understand which societal problems and wants were considered while creating a CE strategy for the Netherlands. Third, policy documents were analyzed on a water authority scale.

Regarding the mission 'execution', desk research was used to identify sustainability ambitions that must be achieved parallel to the circular mission. Expert consultation was used to identify which societal problems and 'wants' were related to specific sub-innovation systems. At least one expert was consulted per sub-innovation system (Appendix B, experts 6,7,8,9). Additionally, data from the interviews (see chapter 3.5) was used.

The relevant technological- and social solutions were analyzed through desk research and expert consultation. Based on preliminary research and contributions by experts (Appendix B, experts 1,2,3), more than one hundred different solutions were identified. According to these field experts, this could be 'the tip of the iceberg', due to many innovations being kept secret by technology developers and consultancy firms (to keep their competitive advantage). Therefore, the following two scoping mechanisms were used to create a more workable overview.

First, regarding technological innovations, solutions were only considered when they reached at least Technology Readiness Level (TRL) 5. These level 5 innovations consist of a *"technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)"* (European Commission, 2017, p. 29). This level was chosen for three reasons. First, there is actual evidence that these innovations can contribute to the mission. Second, circular solutions in the pilot phase are relatively well-known by MIS actors, which is practical for discussion during interviews. Third, by using TRL 5, innovations that are kept secret for competitive reasons (and therefore more difficult to identify) are excluded.

The second scoping mechanism regards which solutions are identified as 'circular'. Due to a lack of consensus regarding the definition of circularity, many 'circular' innovations can be included/excluded based on the used criteria. Based on the 10 RO's model by Reike et al. (2018), this MIS analysis includes circular innovations that contribute to R0-R7 and excludes innovations that contribute to R8 & R9. Both these options are ways of downcycling materials. Although these RO's can be seen as 'circular', they are the least preferred options while trying to achieve a progressive mission.

While taking the scoping mechanisms into account, several methods were used to create the solutions overview. First, document analysis was used to identify solutions. Documents/data were extracted from websites of water authorities, Dutch Water Authorities, research institutes, consultancy firms, technology developers, and network organizations in the Dutch water sector. Previous work by consultancy firm Royal HaskoningDHV (2020) proved helpful, as they created an overview of all circular activities by water authorities. Secondly, eight experts were consulted to review saturation and to add to this overview if necessary (Appendix B, experts 1,2,3,4,5,7,8,9)

The identified solutions were divided per sub-innovation system in the final overview to identify the differences between the sub-systems in the Problem-Solution diagnosis. This process was relatively uncomplicated, as most solutions catered towards a specific sub-system.

## 3.4 Structural analysis

In this stage of the MIS analysis, sub-question 3 and 4 were answered. First, actors that take part in the Mission Arena were identified. Wesseling & Meijerhof (2021) argue that the arena actors have four tasks: *"(1) involving stakeholders in the arena, (2) formulating a mission goal, (3) committing to mission governance actions to mobilize the overall MIS, and (4) engaging in reflexive governance."* (p. 20). For each of these tasks, the relevant actors were identified using policy documents and field expert consultation (Appendix B, experts 2 & 3). The theoretical concept of 'MIS system builder' was used to elaborate on the role of water authorities in creating and modifying the MIS.

Second, other relevant actors, networks, institutions, and materiality were identified. Organizations were identified as MIS actors if they contributed to the development/diffusion of circular innovation relevant to mission success. They were discovered through their mention in/on: policy documents by water authorities, project descriptions, research articles by STOWA (a water authority-specific research institute), branch organization websites (ENVAQUA, Koninklijk Nederlands Waternetwerk), and Winnovatie (platform for innovation related to water authorities). In order to assess if saturation was achieved, the list of actors was reviewed by two field experts (Appendix B, experts 2 & 3). These actors were then categorized in 'actor types' based on their most defining traits.

'Networks' consist of *"structures, which facilitate the exchange of information, knowledge and other resources between innovating actors"* (informal networks) or *"organizational structure[s] with clearly identifiable members where firms and other organizations come together to achieve common aims or to solve specific tasks"* (formal networks) (Musiolik et al., 2012, p. 1034). As an innovation system consists of numerous networks, only the most defining networks of this case study were mentioned. This was done through expert consultation (Appendix B, experts 2,3,5) and complemented by interview statements (see chapter 3.5).

'Institutions' consist of "*the humanly devised constraints that structure political, economic and social interaction. They consist of both informal constraints (sanctions, taboos, customs, traditions, and codes of conduct), and formal rules (constitutions, laws, property rights)."* (North, 1991, p. 97). However, Hekkert et al. (2011, p. 5) state that informal institutions are *"impossible to map systematically"*. Therefore, the authors recommend focussing on "*the formal policies that are in place that are likely to affect the development".* Likewise, only formal policies relevant to the MIS were mentioned in this research. These were identified through expert consultation (Appendix B, experts 2 & 3) and complemented by statements by interviewees.

'Materiality' consists of the *"artifacts and the technological infrastructures"* in which the MIS is embedded (Hekkert et al., 2011, p. 5). These factors differ highly between sub-innovation systems, as their technological structures bear only a tiny resemblance (e.g., wastewater treatment installations have different technological infrastructures compared to flood defenses). Therefore, materiality was identified for each sub-system through consultation of experts of the specific systems (Appendix B, experts 5,6,7,8,9).

## 3.5 System functions

In this stage of the MIS analysis, sub-question 5 was answered. This stage consists of several steps. First, a representative sample of the MIS actors was established based on the Structural Analysis. A generic purposive sampling strategy was used, as the sample was created a priori and is concerned with addressing the research questions (Bryman, 2016). To create a representative sample, three factors were considered. First, the sample included at least one organization of each actor type identified in the Structural Analysis. This meant that at least ten different types of actors had to be interviewed. Secondly, the sample considered this innovation system's unique feature: the structure consisting of 3 sub-systems. Therefore, a similar number of actors were interviewed per sub-system. Third, some actor types had significant scale/size differences internally (e.g., SMEs vs. large contractors & regional vs. national governmental organizations). Due to a high probability of varying views on the innovation processes, the sample consists of organizations of different scales/sizes (Mote et al., 2016).

Based on these three factors, a sample was created consisting of 23 organizations. Table 4 gives an overview of these parties and how these factors were used to create a representative sample.

Table 4: Overview of interview sample, divided by actor type and sub-innovation system

| **Actor Types** | **Interview Sample** | **Wastewater Treatment** | **Flood Defenses** | **Water Level** |
|---|---|---|---|---|
| Regional Water Authorities | 1. Waternet | | | |
| | 2. Waterschap Hollandse Delta | | | |
| | 3. Hoogheemraadschap van Delfland | | | |
| | 4. Waterschap Vallei & Veluwe | | | |
| Governmental Organizations | 5. Provincie Utrecht | | | |
| | 6. Rijkswaterstaat | | | |
| Research Institutes | 7. KWR | | | |
| | 8. STOWA | | | |
| Consultancy & Engineering firms | 9. Tauw | | | |
| | 10. Sweco | | | |
| | 11. Arcadis | | | |
| Technology Developers | 12. NETICS | | | |
| | 13. AquaMinerals | | | |
| | 14. Energie & Grondstoffenfabriek | | | |
| Contractors | 15. Jos Scholman | | | |
| | 16. Van Oord | | | |
| Waste disposal & recycling organizations | 17. HVC | | | |
| | 18. Grond Balans | | | |
| | 19. SNB | | | |
| Financial organizations | 20. NWB Waterinnovatiefonds | | | |
| Network organizations | 21. Unie van Waterschappen | | | |
| Alliances | 22. Biomassa Alliantie | | | |
| | 23. Hoogwaterbeschermingsprogramma | | | |
| Total actor sample per sub-innovation system | | 16 | 17 | 17 |

All interviewees contribute to the transition towards circular water authorities in their daily activities. Most interviewees have backgrounds as policymakers, consultants, innovators, researchers, business developers, advisors, or CEOs.

The interviewees were asked about their (organization's) perspectives on (1) the fulfillment of system functions, (2) the root causes for weak function fulfillment, and (3) governance actions that are/ should be implemented. The questions used in these interviews align with the diagnostic questions on system functions by Wesseling & Meijerhof (2021, p. 11, 12). The interview guide consists of open-and closed questions. The closed questions gave the ability to answer through a Likert scale (1-5). These questions were used to achieve a quantifiable answer from the interviewee on 'strong' or 'weak' function fulfillment. On the other hand, the open questions were used to get more in-depth information about function fulfillment and underlying argumentation. See Appendix C for an overview of the Dutch interview guide (Appendix D for the English translation).

Due to the COVID-19 pandemic, all interviews were conducted via video calling (based on the situation in January 2021) (RIVM, 2021). The interviews were conducted in Dutch, as this is the native language of both the interviewees and the interviewer. This enabled cultural expression and avoided errors of misinterpretation (Becker & Geer, 1957). The interviews had an average length of 01:26:57. The audio was recorded based on informed consent and transcribed afterward. By complete transcription of the recorded audio, the most accurate data was produced for further analysis (Heritage, 1984). This resulted in 537 pages of interview transcriptions.

To analyze the transcriptions, a thematic analysis was used; a common approach to qualitative data analysis which supports the extraction of key themes from the transcripts (Bryman, 2016). It is important to note that this analysis's primary goal is to create a comprehensive overview of the statements made regarding the system functions. Therefore, this thematic analysis is more straightforward than the well-known Grounded Theory approach, which is more iterative and open-ended in nature (Bryman, 2016).

The transcriptions were coded using NVivo 12. 10 different nodes were used, which resulted in 1056 codes:

- Commitment towards circular mission (10 codes)[1]
- SF1: Entrepreneurial activities (105 codes)
- SF2: Knowledge Development (98 codes)
- SF3: Knowledge Diffusion (129 codes)
- SF4A: Problem Directionality (160 codes)
- SF4B: Solution Directionality (125 codes)
- SF4C: Reflexive Governance (82 codes)
- SF5: Market formation and destabilization (148 codes)
- SF6: Resources (re)allocation (78 codes)
- SF7: Creation and withdrawal of legitimacy (121 codes)

Per System Function, the codes were analyzed. Similar codes from different interviewees were summarized in overarching statements. The frequency that different actors made these statements was tracked using a tally sheet. These statements were then divided into four categories (per SF):

- Strengths
- Weaknesses
- Root causes for weaknesses[2]
- Solutions for weaknesses and/or root causes[3]

[1] The node 'commitment towards circular mission' was not used in the System Functions Analysis but was used in the Structural Analysis to understand how certain organizations were committed to the mission.
[2] This category was used sometimes during the System Function Analysis, but was mainly used in the Systemic Barrier analysis to establish the root causes of weaknesses and their interconnections
[3] This category was used sometimes during the System Function Analysis, but was mainly used in 'Reflection on (planned) Governance Actions' stage to identify actions that are proposed/ being taken to address barriers

The overview of statements and the tally sheet were used to write down the results per system function. Statements had to be mentioned at least three times by unique interviewees to be taken up in the results. This decision was made due to (1) the numerous amounts of statements that were mentioned and (2) to avoid potential bias of picking statements that were not mentioned frequently but which would fit an artificial narrative.

In line with the scientific contribution regarding sub-innovation systems, the results per SF include a section with weaknesses specific to either Wastewater Treatment, Flood Defenses, or Water Level. These weaknesses had to be mentioned at least by two unique interviewees to be taken up in the results.

## 3.6 Systemic barriers analysis

In this stage of the MIS analysis, sub-question 6 was answered. During this stage, the weak system functions were analyzed in more detail to deduce which barriers hamper their functioning and how weaknesses were interrelated. Interrelated barriers were also analyzed if they could be linked to potential system lock-in, as described by Wesseling & van der Vooren (2017).

As mentioned in the previous section, all weaknesses and underlying root causes were analyzed and tracked in a tally sheet. The root causes mentioned for most weaknesses could either be directly linked to another weakness or indirectly linked through a similar root cause of another weakness. By connecting the weaknesses through root causes, an interconnected network was created. Due to the numerous amounts of interconnections, some weaknesses were combined into overarching weaknesses. Like the System Function analysis, weaknesses and root causes were only used if they were mentioned at least by three different actors.

As the Systemic Barrier Analysis should give an overview of the barriers hampering the complete MIS, the choice was made against incorporating sub-innovation system-specific barriers. As the barriers are part of a complex interconnected network consisting of feedback loops and potential lock-ins, the usage of sub-system-specific barriers would result in relations that are not generalizable for the entire MIS.

## 3.7 Reflection on (planned) governance actions

In this stage of the MIS analysis, sub-question 7 was answered by analyzing the governance actions. As mentioned in the Theory section, this can be done ex-ante, ex-post, or during the engagement in the MIS (Wesseling & Meijerhof, 2021). As the mission was initiated a relatively short while ago (2017), the third option was deemed most fitting.

However, due to its recency, only a small amount of policy documents was discovered that could be used in this stage of the MIS analysis. This occurrence was backed up by two field experts (Appendix B, experts 3 & 10). Most documents described circular policy on a national scale and were not tailored towards the specific context of regional water authorities (e.g., Ministerie van Infrastructuur en Milieu & Ministerie van Economische Zaken, 2016), or were explicitly tailored towards only one water authority (e.g., Waterschap Vallei & Veluwe, 2018; HDSR, 2020).

Due to the lack of policy documents, on the 13th of November 2020, the '*Commissie Waterketen & Emissies*' initiated the assignment for the phased development of a strategy towards Circular Water Authorities. This resulted in the document "*Het verhaal van de Circulaire Waterschappen*" (The story of the Dutch Water Authorities). This document is the result of the first reconnaissance phase. It includes six policy foci and corresponding actions. In the next phase, these foci will be developed even further and operationalized (Nanninga & Glas, 2021). As this document can be seen as the 'cradle' for the upcoming circular strategy, it is fitting to assess whether the mentioned governance actions address the barriers found in the Systemic Barrier Analysis. Barriers that were not addressed by the document were identified as 'blind spots' in the MIS policy. Complementary governance actions were provided as recommendations.

There are currently no policy documents that contain specific governance actions for Wastewater Treatment, Flood Defenses, or Water Level. However, interview data showed that specific sub-systems could address certain barriers while other systems were hindered by them. These sub-system actions were displayed as viable recommendations for governance action in the overarching MIS.

## 3.8 Reliability & Validity

In order to ensure the rigor of the research, some form of reliability and validity needs to be guaranteed (Morse et al., 2002). According to Bryman (2016), reliability for qualitative research consists of two factors. First, the *internal reliability*, which argues whether researchers would make similar judgments while analyzing certain content. This was assured through the usage of Krippendorff's Alpha while coding transcribed interviews (Krippendorff, 2011). Three researchers, all experienced in MIS analysis, reviewed 30 quotes from the transcribed interview data and labeled these with the most appropriate system function. These labels were compared with the judgment of the writer. This resulted in a KALPHA value of 0.7389 (See Appendix E). De Swert (2012, p. 5) states: *"Kalpha=.80 is often brought forward as the norm for a good reliability test, with a minimum of .67"*. The same author adds that the 'difficulty to code' is an important variable to consider when deciding if a KALPHA score is satisfactory. The <0.8 score was discussed with the reviewers, and the main conclusion was that several statements could be labeled with multiple SFs. This increased the complexity of reaching high inter-rater reliability. Therefore, the score was deemed acceptable for further analysis. Second, *external reliability* deals with the degree that a study can be replicated. It can be challenging to meet this criterion, as there is a chance that the social research setting will change over time (Bryman, 2016). However, all steps taken during the analysis were rigorously recorded, which makes the analysis replicable in a fashion comparable to the original research (LeCompte & Goetz, 1982).

Bryman (2016) mentions that validity for qualitative research can be divided into two factors. First, the *internal validity,* which means *"whether there is a correspondence between researchers' observations and the theoretical ideas that they develop"* (Bryman, 2016, p. 384). This was done by cross-checking results to assure that there is internal coherence between the findings (Riege, 2003). *External validity* is concerned with *"the degree to which findings can be generalized across social settings"* (Bryman, 2016, p. 384). Generalizing findings from a MIS study is complex, as each mission is unique (e.g., different solution pathways, geographical scope, and degrees of complexity) (Wesseling & Meijerhof, 2021). Although the specific case-study results cannot be generalized, the MIS dynamics are generalizable in order to contribute to the theory. This is realized by focusing on theoretical constructs and how they relate to case study results (Riege, 2003), which is elaborated in the Discussion (chapter 5).

# 4. Results

# 4.1 Problem-Solution diagnosis

This chapter consists of two sections. First, the relevant societal problems and 'wants' are discussed related to the mission. Second, an overview is provided of the relevant technological and social solutions.

## 4.1.1 Societal problems and 'wants' related to the mission

As mentioned in chapter 3.1 (case description), a unique attribute of the CE is that circular goals are formulated to positively impact multiple grand societal challenges. However, in practice, there are several trade-offs between societal challenges when trying to operate 'circular'. To take this complexity into consideration, a separation is made between the formulation and execution of the mission. The first part shows which societal problems and 'wants' were of importance while formulating the mission. The second part shows which societal problems and 'wants' are considered while making trade-offs when implementing a circular strategy.

### *4.1.1.1 Formulation of the mission*

Although the mission is explicitly formulated for regional water authorities, it is primarily based on action plans created at the national and EU-level. As problems and 'wants' differ based on the level of analysis, they are discussed on an EU-, national- and water authority-level.

On the **EU-level**, the European Commission created an action plan for a circular economy in 2015. According to this plan, this effort is necessary to *"develop a sustainable, low carbon, resource efficient and competitive economy"* (European Commission, 2015, p. 2).

The action plan was created because the CE is seen as a solution to multiple societal challenges within the European Union. First, CE should protect the EU against resource scarcity and related economic implications. This should lead to more sustainable production and consumption, in line with Goal 12 of the Sustainable Development Goals (SDG's) (European Commission, 2015; United Nations General Assembly, 2015). Second, CE helps to *"avoid the irreversible damages caused by using up resources at a rate that exceeds the Earth's capacity to renew them in terms of climate and biodiversity, air, soil economy, and water pollution."* (European Commission, 2015, p. 2). Third, the CE has to ability to support the EU's key priorities regarding energy, as this new economic model will lead to energy savings and a reduction of $CO_2$ emission (European Commission, 2015).

In 2016, the European Council made its conclusions on the EU action plan for a CE. The Council *"UNDERLINES that the transition to a Circular Economy requires long-term commitment and action, in a wide range of policy areas in the EU, and at all levels of government in Member States; ENCOURAGES Member States to establish and adopt measures and/or strategies to complement and contribute to the EU Action Plan"* (Council of the EU, 2016, p. 1, 2) and *"ENCOURAGES the EU and the Member States, at all levels of government, to actively engage the private sector to promote cooperation, innovation and industrial symbiosis projects within and across sectors and value chains"* (Council of the EU, 2016, p. 2).

On the **national level**, the Dutch government responded to the call to action by the European Council with a national program to make the transition towards a CE. In line with the title of this program, *'Nederland Circulair in 2050'*, it is explicitly stated that it is the goal of the government to develop a completely circular economy before 2050 (Ministerie van Infrastructuur en Milieu & Ministerie van Economische Zaken, 2016).

According to this program, there are three recent developments that make it necessary to strive for a circular economy. First, the demand for resources has increased massively in the last century and will continue to grow due to global population growth and upcoming economies. This increase in demand is not sustainable and will result in environmental problems (e.g., resource scarcity and biodiversity loss). Secondly, the Netherlands is increasingly dependent on resources from foreign (i.e., non-European) countries. Geopolitical tensions, price fluctuations of raw materials, and security of supply will increase worldwide inequality and can have a severe impact on the stability of the Dutch economy. Third, the extraction and usage of resources is energy-intensive and leads to large amounts of $CO_2$ emissions. In order to reach the Paris Climate Agreement, there is a need to reduce overall emissions (Ministerie van Infrastructuur en Milieu & Ministerie van Economische Zaken, 2016).

In 2017, the "Resource-agreement" (*Grondstoffenakkoord*) was recorded, based on the strategy presented in the national program *'Nederland Circulair in 2050'*. In this agreement, governmental organizations, businesses, and civil society organizations shared their ambition to support a swift transition towards a circular economy (Rijksoverheid, 2017). The Dutch Water Authorities also signed this agreement as a representative of the regional water authorities.

On a **water authority-level**, climate change is seen as the most critical driver for the transition towards a circular economy. Especially the longer and more intensive periods of drought and heavy rainfall impact the ability of water authorities to fulfill their responsibilities (Nanninga & Glas, 2021). Recent droughts in the Netherlands have made water authorities more aware that water should be considered as a resource and that the linear economy does not provide a pathway towards a sustainable future (Waterschap Vallei & Veluwe, 2018).

#### 4.1.1.2 Execution of the mission

During the actual transition towards circular water authorities, the mission must be balanced with several different ambitions that are considered at the same time.

In 2017, the Green Deal *Duurzaam GWW* (*Grond-, Weg- & Waterbouw*) was created to support clients and contractors to embed sustainability in civil engineering projects. One of the results of this collaboration is '*Ambitieweb*', which is a tool that supports translating ambitions to concrete demands and wishes for specific projects (Duurzaam GWW, 2021). This tool gives a clear indication of 12 different sustainability ambitions that are considered in projects of regional water authorities (see Table 5). This table indicates that many societal problems are indirectly related to the mission, as they ‘compete’ for priority.

Table 5: Twelve sustainability ambitions and relevant examples, according to ‘*Ambitieweb*’ (Duurzaam GWW, 2021)

| **Sustainability Ambitions** | | **Examples** |
|---|---|---|
| 1. | Energy | energy usage, $CO_2$ emission |
| 2. | Resources | circularity |
| 3. | Water | water quality, water quantity, water safety |
| 4. | Soil | soil quality |
| 5. | Ecology | biodiversity |
| 6. | Usage of space | usage of undeveloped space |
| 7. | Spatial quality | cultural-historical value |
| 8. | Welfare | health, safety |
| 9. | Social relevance | public support |
| 10. | Accessibility | functionality infrastructural system |
| 11. | Investments | costs, profits, added value |
| 12. | Business climate | Employment opportunities |

#### *4.1.1.3 Societal problems and 'wants' sub-innovation system*

Alongside these general societal problems and 'wants' related to the mission, the individual sub-innovation systems have their specific challenges. These mainly consist of situations in which a trade-off/compromise must be made between circularity and the other societal problems.

There are two cases within the **Wastewater Treatment sub-system** in which a trade-off must be made regarding circularity. First, re-cycled materials originating from wastewater can include medicine residues, pathogens, and other harmful materials. At this point, completely circular Wastewater Treatment would have severe implications on human health and the environment. This is one of the main reasons why sewage sludge (the primary residue of the purification process) is not re-cycled but incinerated (mentioned by 2 waste disposal & recycling organization interviewees & 1 field expert (Appendix B, expert 7)).
The second trade-off is between energy savings and circularity. The sewage sludge incineration creates renewable energy. Although incineration is not deemed circular, phasing out this practice will have implications on the energy supply (Appendix B, expert 7).

In the case of the **Flood Defenses sub-system**, there are also two existing trade-offs. The first one is between circular re-use and potential contamination. Soil and dredged material (essential resources in this sub-system) can contain toxic elements (e.g., PFAS). When re-using these materials, there is a potential risk that humans are/ the environment is negatively affected. Therefore, careful consideration of these trade-offs is necessary through risk assessment (mentioned by 1 contractor- and 1 waste disposal & recycling organization interviewee).
The second trade-off is between circularity and $CO_2$ emission. During the maintenance of flood defenses, discharged soil and dredged material are transported. This activity is an important factor in the total emission. In order to reduce these emissions, the materials are re-used in other projects within proximity. Although this practice can be deemed circular, it has drawbacks. It can lead to situations in which the materials could have been re-used for a better purpose (e.g., saving on more virgin materials) on a site at a further distance but were not due to increased transport emission (mentioned by 1 waste disposal & recycling organization interviewee).

The **Water Level sub-system** has two specific trade-offs. First, there is a trade-off between circularity and the entry of hazardous material in the ecosystem/agriculture. Biomass released during mowing activities (around waterways) can be re-used as compost or fertilizer in agriculture. However, the biomass can be contaminated or include hazardous materials. This could negatively impact the soil on which the biomass is deposited (as compost or fertilizer) (mentioned by 1 alliance interviewee).
The second trade-off is between re-cycling and emission. A large portion of the biomass released during mowing activities does not have to be processed by water authorities. Plot owners (e.g., farmers) have a legal responsibility to receive and process the material. Water authorities sometimes claim the biomass in order to increase the volume of their recycling activities. However, this negatively affects their overall $CO_s$-emission due to an increase in transportation (mentioned by 1 alliance interviewee and 2 field experts (Appendix B, expert 8 & 9)).

### 4.1.2 Technological- and social solutions are relevant to the mission

In order to transition towards circular water authorities, there is a need for technological- and social solutions. This section gives a comprehensive overview of how actors (expect to) tackle the mission. Although the 3 sub-systems share the same goal (100% circularity in 2050), their methods/solutions differ considerably. This section will discuss the solutions that were identified per sub-system. Additionally, a social solution will be discussed which is relevant for all three sub-systems.

### 4.1.2.1 Wastewater Treatment

The sub-innovation system regarding Wastewater Treatment has the most significant number of solutions that are developed/ used to make a transition towards a CE. Table 6 gives an overview and description of the technological solutions. Due to the numerous amounts, it is divided into five categories. First, *wastewater treatment installations* include solutions that systematically change how treatments plants work to operate in a circular way. Secondly, circular solutions regarding *wastewater and effluent* include innovative ways to handle water that flows in or out of the treatment plants. The goal is to minimize unnecessary water treatment and delivering a higher quality effluent that has practical uses. Third, solutions regarding *screenings and cellulose* re-use the fiber materials originating from dissolved toilet paper, a prevalent resource in wastewater. Fourth, the category *bioplastics from wastewater* consists of a technology to produce bioplastics through a bacterial process. The fifth category includes circular solutions regarding *sewage sludge,* one of the most significant residues derived from the wastewater treatment process. It is also one of the most contested waste streams for a circular economy, as the sludge is currently transported to incineration plants.

### 4.1.2.2 Flood Defenses

The Flood Defenses sub-innovation system contains the smallest number of solutions to make the transition towards a CE. Table 7 gives an overview and description of the technological solutions in this sub-system. Three of these solutions are related to re-cycling dredged material that is released during flood defense projects. First, 'Topsoil' is a solution that uses dredged material from civil engineering projects as a soil improver in the agricultural sector. Second, an ongoing pilot study uses locally sourced dredged material as building blocks for flood defense reinforcement (as an alternative to concrete). Third, a Dutch start-up uses tiles from dredged material as a substitute for conventional pavement, which supports the transition towards climate-adaptive cities. The final solution is related to re-cycling 'waste' material from other sectors. Discarded fiberglass boat hulls and blades from wind turbines can be used as a sustainable alternative for tropical hardwood in sheet piles.

### 4.1.2.3 Water Level

The Water Level sub-system contains six solutions relevant to the achievement of the mission. Table 8 gives an overview and description of the technological solutions in this sub-system. All solutions are related to re-cycling biomass (i.e. mowed grass in and around waterways). First, two solutions use biomass as a soil improver. 'Bokashi' is a method to ferment biomass, which has multiple advantages compared to composting (the current approach). 'Topsurf' is a specific type of soil improver that can be produced from locally sourced materials yielded from land- and water management (i.a. biomass). Second, four solutions are related to the production of fiber materials. (1) 'Grassbloxxx' is an insulation material that is produced from mowed roadside grass. (2) Roadside weeds can be used to produce mycelium composites, which are valuable resources in insulation- and building materials. (3) In a collaborative effort, water authorities and paper industry actors have identified grass fibers as a valuable material to produce paper and cardboard. (4) A mobile biorefinery has been identified as a promising method for local re-cycling of removed invasive aquatic plants. The technology can be used to produce bio composite fibers, mineral concentrate, and proteins for animal feed.

### 4.1.2.4 Social solutions

In total, only one social solution has been identified (Table 9). '*Waterbazen*' is an initiative from water authorities to raise awareness for water use. Citizens are challenged in a playful manner to do their part in sustainable water management. Examples are: 'replacing garden tiles with sand and soil', 'ensuring that your dog does not dig holes in flood defenses', 'buying a rain barrel to water your plants', etc. These challenges support all three sub-innovation systems in their circular transition. Examples are: (1) the challenge 'do not throw your aquarium plants in a ditch' reduces the number of invasive species in waterways, therefore supporting the Water Level sub-system in reducing the amount of biomass that must be removed and re-used. (2) The challenge: ‘make sure that your dog does not dig holes in dikes’ reduces maintenance and material usage, therefore supporting the Flood Defenses sub-system. (3) The challenge ‘wash your car in a carwash’ reduces the number of harmful substances that enter the sewage system. This supports the Wastewater Treatment sub-system in reducing the materials necessary to purify wastewater.

Table 6: Circular solutions relevant to the Wastewater Treatment sub-innovation system (TRL levels were identified through expert review (Appendix B, expert 7))

| | **Wastewater treatment solutions** | | | | |
|---|---|---|---|---|---|
| **Category** | **Solution** | **Description** | **TRL** | **Retention Option** | **Source** |
| Wastewater treatment installations | Waterfabriek Wilp | *'Water Fabriek'* (Water Factory) is a special type of wastewater treatment plant that produces high quality effluent which can be used by specific clients. It also supports the extraction of materials from wastewater for circular usage. | 7 | Repair, Refurbish | (EFGF, 2019)<br>(Waterschap Vallei & Veluwe, 2021) |
| | Verdygo | Modular system for wastewater treatment plants | 6 | Re-sell/ reuse | (Royal HaskoningDHV, 2020) |
| Circular solutions regarding wastewater and effluent | Decoupling rainwater from the sewage system | Decoupling rainwater is a contested solution with multiple advantages and disadvantages. The main advantage in terms of a circular economy is that rainwater does not infiltrate in the sewage system and therefore isn't unnecessarily purified by a wastewater treatment plant. | 9 | Reduce | (Langeveld, 2019) |
| | Puurwaterfabriek | A '*Puurwaterfabriek*' (Pure water factory) is a wastewater treatment plant that purifies wastewater into 'ultra-pure water' in a process which uses a minimal amount of chemicals. This type of water can be used as steam for oil extraction. | 6 | Re-cycle | (Unie van Waterschappen, 2010) |
| | Delft Blue Water | Method to purify urban wastewater to re-use it as high-quality irrigation water in greenhouse horticulture. | 5 | Re-cycle | (Delft Blue Water, 2021) |
| | Removal of medicine residues and micropollutants from wastewater | Diverse range of technologies (e.g. ozone & PACAS) that can be used to remove medicine residues and micropollutants from wastewater, which leads to an higher quality water out-flow from waste water treatment plants. | 7 | Re-cycle | (Mulder et al., 2019) |
| | Wastewater treatment effluent used as industrial process water | Wastewater treatment effluent used as industrial process water in e.g. a chemical group. | 9 | Re-cycle | (van de Sandt, 2007) |
| Circular solutions regarding screenings/ cellulose | Cellulose as a building material | Cellulose from wastewater has multiple uses as a building material, e.g. as a resource for insulation material or for the creation of fiber board. | 7 | Re-cycle | (EFGF, 2021a) |
| | Cellulose used as activated carbon (through pyrolysis) | Cellulose can be used as activated carbon, which has the ability to remove medicine residue from wastewater. Therefore, cellulose can be retrieved from wastewater treatment plants and directly be re-used in the process. | 5 | Re-cycle | (EFGF, 2021a) |
| | Sieving technology for cleaner cellulose product | Sieving technology that is already used in the paper industry has potential to be used for producing clean cellulose from wastewater, which has the interest of the paper industry. | 6 | Re-cycle | (STOWA, 2019a) |
| | VAZENA (*Van Zeefgoed Naar Asfalt*) | VAZENA (an abbreviation for 'From screenings to asphalt' in English) is a drainage product that can be made from cellulose in wastewater. The product can be used in the asphalt industry. It is specifically useful during the production and transport of asphalt to keep its homogeneity. | 7 | Re-cycle | (STOWA, 2017) |
| Bioplastics from wastewater | PHARIO (*PHA uit RIOolwater*) | PHARIO (an abbreviation for 'PHA from sewage water' in English) is a method in which bacteria purify wastewater and a bioplastic (PHBV) is created. This bioplastic is a high-quality polyester that is completely degradable. | 7 | Re-cycle | (Waterschap Brabantse Delta, 2020) |
| Circular solutions regarding sewage sludge | Struvite extraction from sewage sludge | Phosphate can be extracted from sewage sludge in the form of struvite. This material can be used as a resource to produce fertilizer. | 9 | Re-cycle | (EFGF, 2021b) |
| | Chemical products from struvite | Beside the usage of struvite in fertilizer, there are some pilots that research if struvite can be used in other phosphate rich products. One option is a flame retardant. | 6 | Re-cycle | (EFGF, 2021b)<br>(Wateralliance, 2021) |
| | Nereda purification process | Nereda is a purification technology that changes sewage sludge into settleable granules (instead of flakes). These granules can be extracted and used in a multipurpose material: Kaumera | 9 | Re-cycle | (EFGF, 2021c) |

| | | | | | |
|---|---|---|---|---|---|
| | Kaumera from sewage sludge granules (extracted from Nereda purification process) | Kaumera is a material that has multiple uses: i.e., as a lightweight bio composite, a retainer of fertilizer in agriculture or as a coating for concrete | 7 | Re-cycle | (EFGF, 2021c) |
| | Vivimag | Vivianite is a phosphate mineral that can be extracted from sewage sludge and can be used (1) as a blue pigment, (2) in batteries and (3) in fertilizer. Extracting Vivianite is cheaper and has more extraction potential compared to struvite. | 6 | Re-cycle | (Unie van Waterschappen, 2021e) |
| | Neutral powder (building material) from sewage sludge | Neutral powder is a building material that can be extracted from sewage sludge using a new method called 'Mid Mix' | 6 | Re-cycle | (van den Bulk & Vergnes, 2019) |
| | Bio-granulate (fertilizer) from sewage sludge | Nutrients originating in sewage sludge can be used to create bio granulate, which has its use as fertilizer in agriculture. This solution supports closing the phosphate cycle. | 6 | Re-cycle | (EFGF, 2021b) |
| | Bio-bitumen from sewage sludge and screenings | Wet organic waste streams can be used as bio-bitumen through high pressure and temperature. This can be used as an alternative for bitumen made from fossil resources. | 6 | Re-cycle | (Winnovatie, 2021) |

Table 7: Circular solutions relevant to the Flood Defenses sub-innovation system

| Flood Defenses solutions | | | | |
|---|---|---|---|---|
| **Solution** | **Description** | **TRL** | **Retention Option** | **Source** |
| Dredged material as building block for flood defense reinforcement | In order to reinforce dikes in the Netherlands, elements made from concrete are used. These are expensive and unsustainable (both in terms of production and transport). However, an ongoing pilot study tries to substitute concrete by using locally available dredged material. This is a more sustainable material and gives a useful destination for a resource that has previously been deemed as a waste-stream. | 5 | Re-cycle | (Schouten et al., 2020)<br>(H2O Waternetwerk, 2021) |
| Pavement from dredged material | In order to create climate-adaptive cities, the start-up 'Waterweg' has created tiles from dredged material as a substitute for conventional pavement. The dredged material can be sourced from local rivers. | 5 | Re-cycle | (Waterweg, 2021) |
| Topsoil | Topsoil is a solution that connects sustainability challenges from the Dutch civil engineering sector with the agriculture sector. Soil and dredged material that is released from civil engineering projects (e.g. managing flood defenses) can be processed into a soil improver for farmers. The advantages are: (1) local sourcing (cheaper and more sustainable in terms of transport), (2) increased ability of the soil to bind carbon, and (3) prevents subsidence. | 5 | Re-cycle | (SRSS, 2021a) |
| Flood defense sheet piles from composite plastics | Currently, most sheet piles used in Flood Defenses are made from tropical hardwood. This material is very sustainable in terms of lifespan but has a large ecological footprint. As an alternative, pilot studies have used composite plastics. Initial results seem promising. These composite materials can be sourced from discarded fiberglass boat hulls and blades from wind turbines. | 5 | Re-cycle | (NJI, 2021) |

Table 8: Circular solutions relevant to the Water Level sub-innovation system

| Water Level solutions | | | | |
|---|---|---|---|---|
| **Solution** | **Description** | **TRL** | **Retention Option** | **Source** |
| Mobile biorefinery for aquatic plants | Water authorities must deal with an increase in invasive aquatic plant species, which need to be removed. Biorefinery is a promising solution for value retention of this stream of biomass. While biorefineries are commonly perceived as methods for biogas production, they can also be used for the creation of a diverse range of products. Examples are bio composite fibers, mineral concentrate and proteins for animal feed. | 6 | Re-cycle | (van Doorn, 2018) |
| Bokashi | Bokashi is an alternative method to composting biomass. Instead of composting, the biomass is fermented. This Japanese method produces an effective soil improver that can be used in agricultural settings. The advantages compared to composting are: (1) shorter process time, (2) less weed growth and (3) less nutrient leaching. | 9 | Re-cycle | (Royal HaskoningDHV, 2020)<br>(Waterschap de Dommel, 2021) |
| Paper from biomass | In the project *'Van Berm tot Bladzijde'* ('From roadside to paper page' in English), the fibers from roadside grass have been successfully used to produce paper/cardboard. This project is a collaboration between, among others, water authorities, municipalities and organizations in the paper industry. | 6 | Re-cycle | (SRSS, 2021b) |
| Mycelium composites from biomass | Roadside weeds, which are removed by water authorities, could be used to produce mycelium composites. These composites are a valuable resource for insulation- and building materials. | 5 | Re-cycle | (STOWA, 2019b) |
| Grassbloxxx | Grassbloxxx is an insulation material and building panel that is made from mowed roadside grass (biomass). It is produced by the Swiss firm Gramitherm and has already been used in Switzerland and France. The product has a smaller environmental impact than the current practice of composting biomass. | 9 | Re-cycle | (Royal HaskoningDHV, 2020)<br>(Cirkelstad, 2020) |
| Topsurf | Topsurf is a specific type of soil improver that can be made from locally sourced materials that are yielded from land- and water management (e.g. biomass and dredged material). Through local re-use, these materials add value to the soil quality and -structure and reduce transport costs & -emission. | 5 | Re-cycle | (Unie van Waterschappen, 2018) |

Table 9: Circular social solutions, relevant to the Wastewater Treatment, Flood Defenses & Water Level sub-innovation system

| Social solutions | | | |
|---|---|---|---|
| **Solution** | **Description** | **Retention Option** | **Source** |
| Waterbazen | 'Waterbazen' is an initiative from water authorities to raise awareness for water use. Citizens are challenged in a playful manner to do their part in sustainable water management. Examples are: replace tiles in the garden with sand and soil, don't let your dog dig on flood defenses, buy a rain barrel to water your plants, wash your car in a car wash, don't throw your aquarium plants in a ditch, etc. | Refuse, Reduce | (Unie van Waterschappen, 2021f) |

# 4.2 Structural Analysis

As mentioned in the Methodology section, the system components were identified (i.e., actors, institutions, networks, and materiality), which make up the structure of the innovation system (Hekkert et al., 2011; Wanzenböck et al., 2020). A distinction is made between the 'Mission Arena' and the 'overall MIS'.

## 4.2.1 Mission Arena

In this specific case study, 23 different actors were identified as the partitioners in the mission arena, consisting of 21 regional water authorities, the Dutch Water Authorities, and the *'Energie & Grondstoffen Fabriek'* (commonly referred to as 'EFGF'). These actors are/ were engaged in at least one of the four tasks of a Mission Arena, which are elaborated in the upcoming paragraphs.

### *4.2.1.1 Setting up the Mission Arena*

In this specific case study, the Mission Arena was not created anew. Instead, it used already-in-place structures. Long before the mission was posed, water authorities mobilized other organizations due to their role as decentralized managerial governments. This creates a power dynamic in which water authorities are central in developing *"networks that enable effective mobilization and redirection of existing innovation systems structures"* (Wesseling & Meijerhof, 2021, p. 7). This is related to their previously established role as 'MIS system builders'. They have an essential role in creating a well-functioning innovation system (and inherently setting up the Mission Arena).
Furthermore, the Dutch Water Authorities play an essential role in setting up the Mission Arena by developing networks. This organization has a crucial role in ensuring open discussion, knowledge diffusion, and collaboration between regional authorities. This actor is also the primary advocate for the collective interests of water authorities in national and international (political) contexts (Unie van Waterschappen, 2021g).
Additionally, the EFGF supports the innovative capabilities of the MIS. In 2008, water authority employees started working on a route to couple wastewater treatment to more significant societal problems such as water-, energy- and resource scarcity. This project resulted in the EFGF, which now operates as an independent enterprise. For more than a decade, this organization has been pioneering in the transition towards 'circular' wastewater treatment. When the mission towards a CE was posed in 2017, the sector already created a dedicated actor for the governance of circular innovations. This is also the main reason why the Wastewater Treatment sub-innovation system already has many more solution pathways available compared to other sub-systems (see Problem-Solution diagnosis). At this point, the EFGF has branched out its activities and supports the Water Level sub-system with circular usage of biomass. (N.B. The EFGF is funded by the regional water authorities.) (EFGF, 2021d; mentioned by 1 technology developer interviewee)

There were no non-governmental actors identified that define, influence, or provide recommendations to the mission. The water authorities did not seem to bring any other actors on board to contribute to mission governance tasks.

According to Wesseling & Meijerhof (2021), an important characteristic of the Mission Arena is the inherent conflict on the employed methods. Even though water authorities have the same core activities and seem like-minded, their policies and priorities are not entirely aligned. Like provinces and municipalities, the administration (*bestuurders*) of a regional water authority is decided through public election (ProDemos, 2021c). These administrations are responsible for the preparation and implementation of policy. Socio-economic and geological differences per region result in administrations with diverse priorities and policies (mentioned by 3 interviewees: 1 network organization, 1 water authority, 1 technology developer). This results in the necessary contestation on mission governance.

#### 4.2.1.2 Mission formulation

As previously mentioned, the *'Grondstoffenakkoord*' was recorded in 2017. In this agreement, all signatories agreed to support the development of a CE by 2050 in the Netherlands (Rijksoverheid, 2017). This agreement was also signed by the Dutch Water Authorities on behalf of the 21 regional water authorities (Unie van Waterschappen, 2018). Based on what is established by the *'Grondstoffenakkoord'*, the Dutch Water Authorities formulated the mission "100% circular water authorities in 2050" (Nanninga & Glas, 2021).

#### 4.2.1.3 Mobilization of MIS components via mission governance actions

Wesseling & Meijerhof (2021, p. 8) mention that this task *"requires an overall mission agenda or action plan that includes not only the activities that existing innovation system structures need to pursue, but also the governance actions that incentivize and enable these structures to undertake such activities."* This 'action plan' was recently published by the Dutch Water Authorities, after being critically reviewed by sustainability/circularity experts and administrations of regional water authorities (Nanninga & Glas, 2021; Appendix B, expert 10). This plan is also discussed in the 'Reflection on (planned) governance actions'. All Mission Arena actors mobilize MIS components through governance actions (see Chapter 4.5).

#### 4.2.1.4 Reflexive mission governance

While reflexive mission governance consists of many activities (Wesseling & Meijerhof, 2021), this Mission Arena currently focuses on monitoring mission progress. The Dutch Water Authorities mobilizes every water authority to gather data on their circular progress. Regional authorities obtain this data from their operations and by retrieving it from other MIS actors (e.g., contractors) (mentioned by 3 interviewees: 1 water authority, 1 contractor, and 1 network organization).

### 4.2.2 Overall MIS

The overall MIS consist of the mission arena and a much larger group of other actors, networks, institutions, and materiality that support the transition towards circular water authorities.

#### 4.2.2.1 Actors

A list of 93 actors was identified as contributors to the MIS. In practice, this list is much more numerous. Most regional actors were not included in this list (e.g., all 355 Dutch municipalities). These actors were categorized into ten different 'actor types'. These ten categories were deemed as representative of the MIS according to field experts (Appendix B, experts 2 & 3). All actor types have their distinct role in the transition towards circular water authorities. An overview is presented in Table 10. This overview also includes the Mission Arena actors. The regional water authorities are named as such, the EFGF is part of 'Technology Developers', and the Dutch Water Authorities is part of the 'Network Organizations'.

There are two relevant notes on these actor types. First, the actor types are not entirely mutually exclusive, as some actors perform multiple roles in the MIS. This meant that a few actors could be categorized into multiple actor types (e.g., Dutch Water Authorities can be a network organization or a governmental organization). Second, based on the established concept of 'sub-innovation systems', some specific actors only contribute to one or two sub-system(s) (e.g., a firm that manages a sewage sludge incineration plant only contributes to Wastewater Treatment). However, there were no actor types identified that were limited to a specific sub-innovation system. Each actor type included representative actors from all three sub-innovation systems.

Table 10: Overview of the 'actor types' and roles within the MIS

| **Actor type** | **Role in MIS** |
|---|---|
| Regional Water Authorities | Central figures in the mission (system builders), owners of important assets (e.g. wastewater treatment installations, flood defenses, pumping stations, etc.), mobilizes other actors in the MIS |
| Governmental organizations | Collaborating with water authorities and aligning assets/infrastructure (e.g. sewage systems from municipalities, flood defenses from Rijkswaterstaat) to enable the circular transition |
| Research institutes | Supports through scientific insights to understand the related societal problems and provide solution pathways |
| Consultancy & engineering firms | Provides (advice on) practical solutions for implementing circularity in regional water authority projects |
| Technology developers | Develops innovative circular solutions to tackle the grand societal challenges related to the mission |
| Contractors | Take on commissions from water authorities and make sure that the core activities are executed in a circular way |
| Waste disposal & recycling organizations | Disposes/ recycles materials flowing out of the industrial processes of regional water authorities |
| Financial organizations | Finances circular projects/innovations |
| Network organizations | Facilitates communication & knowledge diffusion between actors, advocates the collective interests in wider context (nationally and internationally) |
| Alliances | Enables collaboration between actors to reach a specific circular goal more efficiently |

#### *4.2.2.2 Commitment to the mission*

One unique element of this specific MIS is that non-Mission Arena actors did not sign an official agreement to support the achievement of the mission. Therefore, during interviews, non-Mission Arena actors were asked how they were committed to the mission. In general, four types of commitment were found.

First, several actors signed the '*Grondstoffen Akkoord*', therefore committing to the general notion of 100% circularity in 2050. These actors include governmental organizations and some of the waste disposal & recycling organizations, technology developers, alliances, consultancy & engineering firms, and research institutes (Rijksoverheid, 2020).
Second, some actors have a regional water authority as a shareholder and are therefore indirectly committed to this mission. This group consists of some technology developers and waste disposal & recycling organizations.
Third, some actors have water authorities/ governmental organizations as their main clients. In order to keep their clientele, these actors (primarily contractors) must move along with governmental sustainability ambitions.
Finally, the last category consists of actors that do not have a direct commitment to the mission but move towards the same goal. Some of these organizations have construed strict personal goals, while others only express their intention. This category includes mostly consultancy & engineering firms and research institutes.

#### *4.2.2.3 Networks*

Within the MIS, there are a few notable remarks regarding networks. First, many already established networks are used. Networks of actors were created to contribute to wastewater treatment, the

management of flood defenses, and the regulation of water levels. These previously established networks are now used for the circular transition.
Second, a few networks are specifically designed to contribute to the circular transition. Examples are: (1) the 'Biomass Alliance' (*Biomassa Alliantie*), a collaboration between governments and research institutes for value retention of mowed biomass (Biomassa Alliantie, 2018). (2) 'Circular Ateliers' (*Circulair Ateliers*) is a bi-monthly initiative by the Dutch Water Authorities to connect policymakers and sustainability experts from different water authorities to discuss the interpretation and progress of the mission (Ministry of Infrastructure Water Management et al., 2021).
Third, the networks have a distinct national character. Most actors solely operate in the Netherlands, and the interaction with international actors is limited (mentioned in interviews by 2 water authorities). The international context was only relevant when the circularity-related interests of the MIS were advocated in EU politics (mentioned by 1 network organization interviewee).

#### *4.2.2.4 Institutions*

Two formal policies affect the development and diffusion of circular innovations in the MIS. First, in 2019, the Ministry of Infrastructure and Water Management & the Dutch Water Authorities commissioned a task force to assess the influence of regulation on the ability to transition towards a CE. This assessment resulted in the identification of multiple regulatory obstacles, e.g. (1) ambiguous definition of 'waste' in European- & national regulation, (2) lack of concrete criteria to establish when a resource no longer must carry the 'waste' predicate (*einde-afvalstof*), and (3) permits give insufficient room for experimentation to retain the value of waste (Sorgdrager et al., 2019).
Second, the relationship between water authorities and non-governmental actors is primarily shaped by the formal institution of 'tendering regulation'. This entails that whenever an organization delivers works, goods, or services above a certain financial threshold to a government, official tender procedures should be followed. One of the implications is 'equal treatment', in which governments are obliged to treat every firm equally and share the same information (Netherlands Enterprise Agency RVO, 2021). This has implications for the relationships that can be built within the innovation system.

#### *4.2.2.5 Materiality*

Materiality is an important system component on the sub-innovation system level. Each sub-system has its own technological structures or artifacts (Hekkert et al., 2011) that are relevant to the circular transition. Most of these are governed by water authorities.

Regarding Wastewater Treatment, the sewage infrastructure and wastewater treatment plants are essential material factors. These structures transport and purify sewage water before it is discharged in e.g., rivers and canals. These structures are the target of many circular innovations (see table 6). Within this sub-system, sewage infrastructure is governed by municipalities, while treatment plants are governed by water authorities (mentioned by 1 governmental organization interviewee and 1 waste disposal & recycling organization interviewee).
The Flood Defenses sub-system consists of a large and complex infrastructure of flood defenses, e.g., dikes, dunes, quays, and dams. Some of these are governed by Rijkswaterstaat. However, most of these are the legal responsibility of their respective regional water authority (Unie van Waterschappen, 2021h).
The materiality of the Water Level sub-system consists of a complex infrastructure of pumping stations and weirs present in the Netherlands. However, most circular innovations focus on biomass, which is removed in and around waterways through mowing (see Table 8). Overall, the pumping stations and weirs are governed by the water authorities, while mowing technologies are managed by contractors (mentioned by 1 alliance interviewee and 2 field experts (Appendix B, experts 8 & 9))

# 4.3 System Functions

Based on the Structural Analysis, and as explained in the Methodology, 23 interviews were conducted with different MIS actors to obtain an overview of the fulfillment of the nine system functions. This chapter first discusses the system function scores that actors gave. Secondly, it will discuss the argumentation given by interviewees for strong/weak fulfillment per system function.

## 4.3.1 Grades per system function

As mentioned in the Methodology, each interviewee was asked to grade the fulfillment of the individual system functions with a score between 1 (lowest) and 5 (highest). Figure 2 (a radar chart) displays the scores that were given per system function, combined per actor type. The figure also includes the average given score per system function, indicated by the red dotted line.

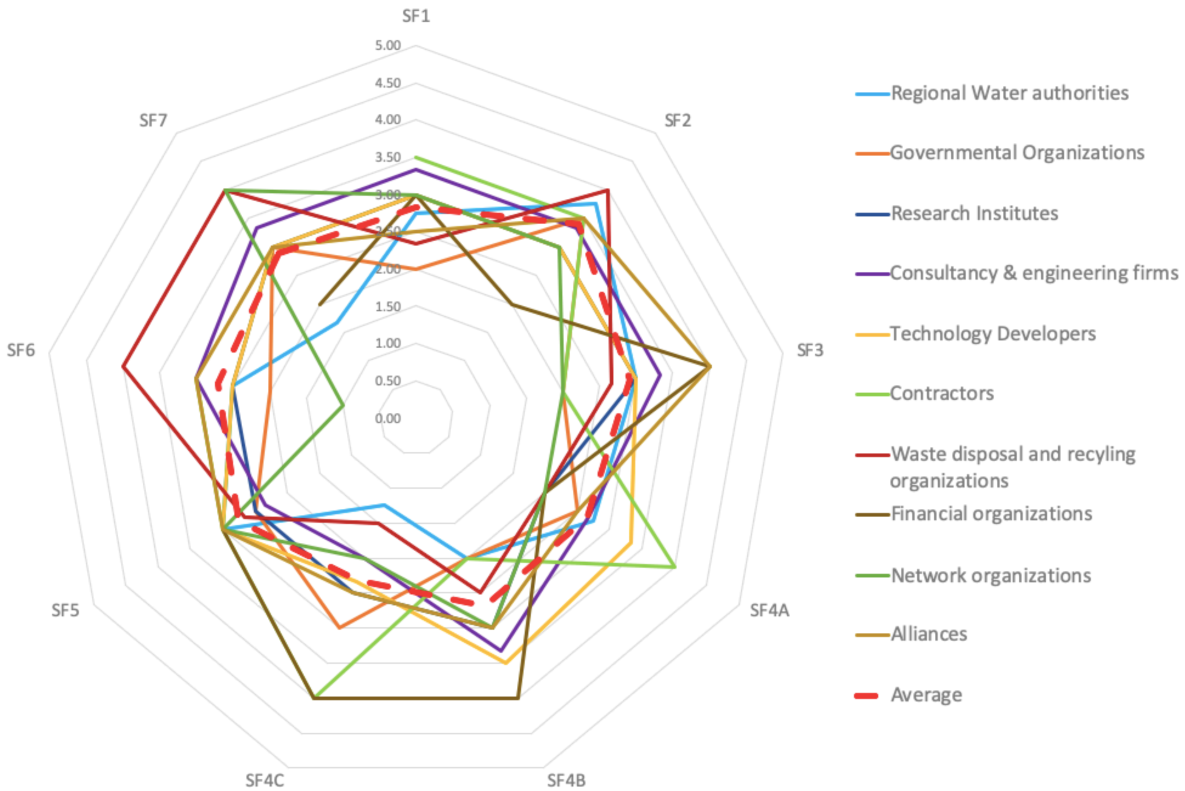


Figure 2: Average scores given by 10 actor types on the fulfillment of 9 system functions (visualized in a radar chart)

As the figure indicates, there are not many fluctuations in the average score given per system function. This is shown by the red dotted line, as it seems to uphold a relatively round shape outside of a small spike regarding SF2. Overall, the system functions were averagely scored between 2.32 (SF4C) and 3.39 (SF2). This seems to indicate that the interviewees did not believe that any system functions were extremely weakly fulfilled. However, they did not consider the SFs adequately fulfilled either. The only striking feature is that the SFs regarding directionality received the overall lowest scores, respectively a 2.32 (SF4C), 2.65 (SF4A), and 2.68 (SF4B).

When comparing the scores per actor type, there is a fluctuation between 1.00 (SF6) and 4.00 (multiple SFs). With some exceptions, most of the actor types scored the SFs in a relatively similar fashion, as the chart shows that most of their lines follow a similar trajectory as the average score (red dotted line). One notable exception is that SF4C received a low score (1.25) from regional water authorities, while it received a high score (4.0) from contractors. This difference can be explained based on their opposing views on monitoring (elaborated in the description of SF4C).

The differences between the scores of the Mission Arena and non-Mission Arena actors were also analyzed (Figure 3). As revealed by this figure, the Mission Arena actors gave a lower score to most of the SFs than non-Arena actors (respectively SF4A, SF4B, SF4C, SF6, SF7). The non-Arena actors gave the lowest score on four SFs. However, these scores are only slightly lower than the ones given by the Mission Arena (respectively SF1, SF2, SF3, SF5). This seems to indicate that the Mission Arena considers the system functions less adequately fulfilled, especially SF4C and SF6.

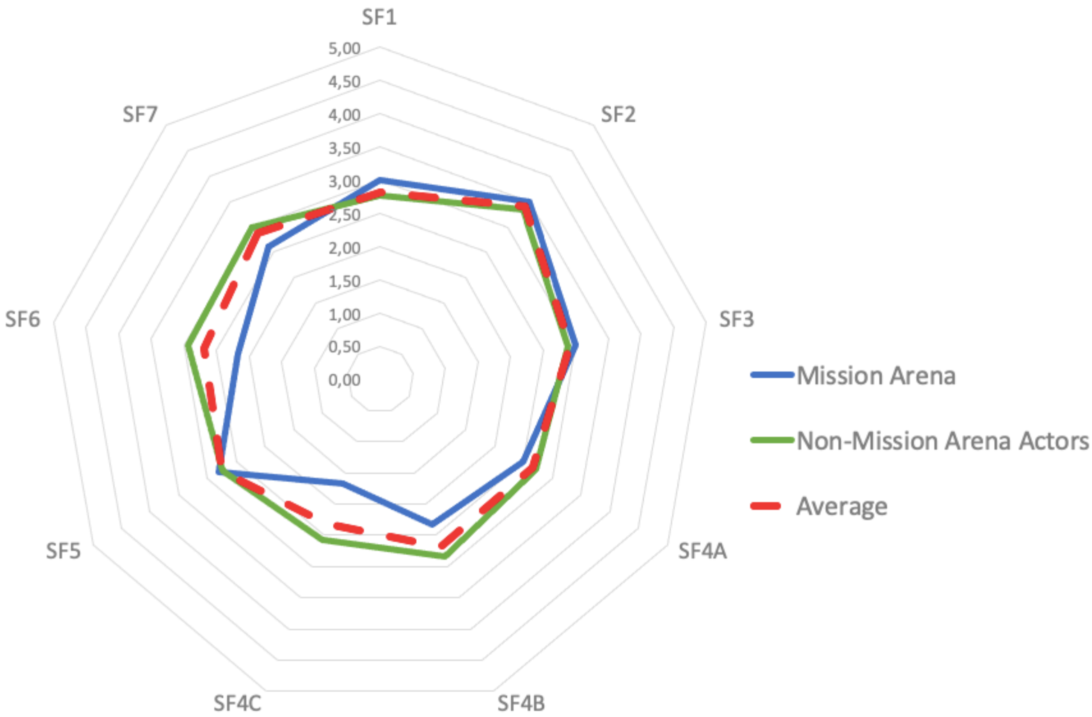


Figure 3: Average scores given by the Mission Arena and Non-Mission Arena actors on the fulfillment of 9 system functions (visualized in a radar chart)

Additionally, a radar chart was made to compare scores that were given per sub-innovation system. However, this chart showed that there were negligible differences between the sub-systems. The radar chart for the sub-innovation systems can be found in Appendix F.

## 4.3.2 Descriptions of system function fulfillment

The upcoming sections discuss the argumentation given by interviewees for strong/weak fulfillment per system function.

### *SF1: Entrepreneurial Activities*

Actors scored SF1 with an average score of 2.83 (N=23), which is a neutral score. The highest average scores were given by the contractors (3.5) and consultancy & engineering firms (3.33). The lowest scores were given by governmental organizations (2.0) and waste disposal & recycling organizations (2.33). Both actor types included at least one interviewee that scored SF1 with a '1.0'.

According to the interviewees, the MIS has multiple strengths regarding SF1. There is much circular experimentation within the system, as many pilot projects were initiated (mentioned by 10 interviewees). Firms[4] show entrepreneurship and/ or are innovative, even when the water authority seems to be passive (mentioned 8 times). Multiple interviewees mentioned an incentive to experiment with circular innovation due to clear economic benefits, existing pressure, or upcoming pressure by future regulation (e.g., regarding nitrogen) (9x). Within the Mission Arena, there seems to be a small group of very passionate employees that push water authorities to enhance their circular entrepreneurship (5x). Last, according to some, the EFGF fulfills an important role in supporting the entrepreneurial activities of the water authorities (3x).

Interview data also resulted in multiple weaknesses regarding SF1, some of which contradict the abovementioned strengths. First, interviewees mentioned that water authorities lack a proactive attitude regarding entrepreneurship (9x). The number of entrepreneurial activities for circularity is very dependent on the amount of support from the administration (9x) (elaborated in SF7). Furthermore, a heavy focus on the core activities results in a lack of priority for circular entrepreneurship (4x) (elaborated in SF4A).
Secondly, water authorities do not seem to stimulate firms to be entrepreneurial and engage in circular projects. The requests that water authorities make in project tenders are seen as insufficiently clear and/or ambitious (9x). This lack of 'asking the right questions' is considered by some as a result of a lack of understanding/vision of what a circular economy looks like (SF2) (4x).
Related to the first and second statements, many interviewees mentioned that firms also lack a pro-activity regarding circular entrepreneurship (10x). This was most visible during the tender phase or in circular development projects. The ambiguous requests by water authorities inherently mean that firms must come up with a detailed solution. However, during tenders, firms are judged on how expensive their solutions are. Strict tendering regulation limits the possibility to discuss more elaborate plans with water authorities (3x). This means that firms can 'price themselves out of the market' when a proposed circular solution is deemed 'too expensive' (3x). Therefore, firms want to 'keep their cards close to their chest' and wait for a water authority to make a more concrete request (5x). This creates a form of 'stand-off' in which both actor types are waiting for the other.
Fourth, multiple interviewees mention that although many pilots have been initiated, it remains a non-strategic activity (6x). One interviewee who is part of the Mission Arena mentioned that it sometimes feels *"like some kind of hobby club, where they are tinkering, but there is not much result regarding scale-up"* (translated from Dutch). The lack of direction regarding pilots (SF4B) results in a feeling that the MIS is possibly 'reinventing the wheel' at different places.

Two differences between sub-innovation systems were mentioned regarding SF1. Interviewees mentioned multiple times that Flood Defenses & Water Level get less attention, or are less developed, in terms of circular entrepreneurship compared to Wastewater Treatment (4x). An interviewee explained this phenomenon as a result of the EFGF: *"In terms of circularity, I believe that Wastewater Treatment is very active because of the EFGF. They have recognized this ten years ago and are therefore really a frontrunner and are now also lightyears further in knowledge and organization than Water Level and Flood Defenses"* (1 Technology developer, translated from Dutch). Secondly, multiple actors operating in Flood Defenses & Water Level mentioned that some contractors exploit the circular entrepreneurship by water authorities for personal gain. Firms (primarily contractors) promise to work in a circular way when taking on the project but do not always comply in practice or exploit the circular inquiry (e.g., by deliberately increasing the number of materials used in a project, as they are compensated for the volume of circular re-use) (4x).

[4] When the term 'Firms' is used, the following actor types are meant: consultancy & engineering firms, technology developers (excl. the EFGF), contractors, and waste disposal & recycling organizations. (N.B. This term is not used as a synonym for 'non-governmental actors')

## *SF2: Knowledge Development*

Actors scored SF2 with an average score of 3.39 (N=23), which is the highest average of all nine system functions. The highest average scores were given by waste disposal & recycling organizations (4.0) and regional water authorities (3.75). On the other hand, financial organizations (2.0), research institutes (3.0), and technology developers (3.0) scored SF2 the lowest on average. One interviewee (water authority) gave SF2 a perfect score (5.0), and zero interviewees gave a 1.0.

Multiple strengths were mentioned regarding knowledge development in the MIS. First, several actors/initiatives were mentioned as important supporters of SF2, namely: STOWA (8x), research institutes in general (8x), universities (7x), the EFGF (3x), and CB23 (3x). Second, several types of research on circularity were mentioned. According to interviewees, there is much ongoing research on how to retrieve/ re-use resources that can be found in wastewater treatment (8x). There is also ongoing research on making construction materials out of dredged material (4x) and how to re-use biomass in a circular way (3x). On a more abstract level, the Dutch Water Authorities are performing reconnaissance on what a circular economy would mean for regional water authorities (3x). Multiple actors are researching how to monitor/assess circularity (e.g., the measuring framework by RIVM & PBL, DuboCalc, an app for dredging projects by STOWA) (7x). Additionally, water authorities try to create material flow analyses based on their operations (3x).

Nevertheless, multiple weaknesses were also identified based on the interview data. Generally, multiple actors mentioned that knowledge development is going too slow (4x). Three distinct types of SF2 weaknesses were identified. First, multiple knowledge questions are still unanswered. These include a lack of understanding (1) what a circular economy is and/or what it will look like (12x), (2) what you can do with a circular economy/ how it can be implemented in the daily work processes (11x), (3) what the benefits are (3x), and (4) what the social aspect entails (3x).
Secondly, there seems to be some ambiguity regarding the 'larger perspective' of circular water authorities. Circular solutions and knowledge development currently focus on a 'narrow' definition of circularity, in which water authorities purely try to find a purpose for their own ‘waste’ materials. There seems to be a lack of attention on how these solutions are linked to the larger societal challenges and the common interest (3x). It was also mentioned that it is unclear for water authorities which role they should play in societal transitions (3x). One interviewee aptly mentioned: *“[current research] is too restrictive. You need to look at the larger societal challenge. Zoom out to the common interest. (…) You need to prevent that you zoom in on one specific aspect, such as $CO_2$-emission reduction or upgrading specific resources. You should look at: “How can we couple the re-use of resources with other themes, such as micro contaminants, nano plastics, etc.””* (1 water authority, translated from Dutch).
Finally, there are a few knowledge questions regarding how to deal with direction/ leadership. Interviewees mentioned that the water authorities, together with Rijkswaterstaat, develop a lot of knowledge without a proper strategy (5x). Related to that statement, the question was posed which actors should take leadership regarding knowledge development (water authorities, STOWA, or another actor) (4x).

There were some SF2 weaknesses mentioned that were specifically related to sub-innovation systems. Most of these were related to Flood Defenses, as this sub-system struggles with the question of how circularity is relevant for them and/or if their current practices are already circular (3x). Long before the term 'circularity' got any traction, it was already standard practice in soil- & dredging projects to re-use materials. Soil extracted from one project could be used as a resource for another project. This practice is mostly cost-driven. The transition towards 'circular' flood defenses poses new questions on what is already circular and what should change. Multiple interviewees mention that the sub-system focuses on optimizing research flows and less on how to 'close the loop' (3x). Others mention that

there is no circular waste hierarchy for the re-use of soil and dredged material (3x). This results in a situation in which high-quality retention of soil is valued similarly to low-quality retention of soil.
One SF2 weakness was specifically tailored to the Wastewater Treatment sub-system. Two waste disposal & recycling organizations mention that there is still a lack of understanding of what to do with the harmful/toxic residue that remains from wastewater treatment (2x). This lacuna in knowledge is an important barrier in the transition towards *100%* circularity.

## *SF3: Knowledge Diffusion*

Actors scored SF3 with an average score of 2.91 (N=23), which is the second-highest average of all nine system functions. The highest average scores were given by the financial organizations (4.0) and alliances (4.0). The lowest average scores were given by governmental organizations (2.0), contractors (2.0), and network organizations (2.0).

Interview data shows multiple strengths regarding SF3. Many interviewees mentioned that there is a lot of knowledge diffusion within the MIS (9x). Conferences, webinars, and reports were identified as important media for diffusion (15x). Within the Mission Arena, the Dutch Water Authorities supports knowledge diffusion between water authorities, e.g., through '*circulair ateliers*' (a bi-monthly circularity meeting/workshop), masterclasses, and sharing examples and experiences (6x). Water authorities use the EFGF and a system of '*koplopergroepen*' (teams of water authorities that take the lead in a specific circular challenge) to diffuse knowledge (5x). In the overall MIS, there are several collaborations between water authorities, universities, consultancy firms, contractors, branch organizations, and research institutes (e.g., WiCE, ROK ITA, Duurzaam GWW, Infra Innovatie Netwerk, CB23, Nutriënten Platform, Water Test Network) (15x). Water authorities also look for collaboration within their regional networks (3x).

There are also multiple weaknesses mentioned by actors regarding SF3. Generally, it is seen as challenging to share knowledge between organizations (3x). Although diffusion can be seen as a strength, some mentioned that large amounts of knowledge diffusion could make it complicated/chaotic to find information (3x). Additionally, many interviewees mentioned a lack of coalitions between actors that pledge to work on a specific circular challenge (for a more extended timeframe). There is a lack of/ need for more collectivity (10x).
Most other SF3 weaknesses can be divided into four different categories. First, there is insufficient knowledge diffusion within water authorities. Interviewees mention that knowledge on circularity is dependent on just a few experts (6x). This is reinforced by the statement that diffused knowledge (e.g., reports) is mainly addressed at people already knowledgeable on the subject, making it hard to understand for the administration and other employees (4x). Additionally, conversations between CE experts and process experts within water authorities still must determine what the actual barriers are in the daily work processes (3x).
Second, there are five weaknesses mentioned related to the general communication between water authorities and firms. (1) Water authorities diffuse less knowledge to the overall MIS than the Mission Arena (5x). (2) Collaboration/ diffusion of knowledge between water authorities and firms can be blocked by the discussion about Intellectual Property (IP) and license income (4x). Partners believe that there is an unfair distribution of cost and benefits (4x). For example, water authorities find it unfair that firms can gain substantial financial benefits internationally from a collaborative effort. (3) Firms are entirely focused on winning a tender, therefore creating proposals that seem more circular than they are, resulting in less open- and transparent information/dialogue (5x). (4) Water authorities (and other governmental organizations) are not always receptive to the knowledge shared by firms (6x). Water authorities make strict descriptions of what the tender looks like, which does not give firms room to add ideas during the project. This is explained by a desire to take away risk at the start of a project and a 'fear' to show favoritism (3x). (5) Insufficient communication results in a lack of

understanding by water authorities what contractors did with the 'waste' material after finishing the project.
Third, similarly to SF2, actors find it difficult to look at the 'larger perspective' of the mission. The knowledge diffusion is mainly within the sector and between the 'usual suspects' (5x). Water authorities also seem to forget to consider all stakeholders or take the whole value chain into account (4x).
Fourth, actors have very different 'philosophies' on knowledge diffusion. Water authorities want to share knowledge openly between actors while firms (contractors & consultancy firms) keep their knowledge to themselves (7x). Multiple interviewees mentioned that firms are not proactive in sharing knowledge (7x) and 'keep their cards close to the chest' based on a fear that they could lose their competitive advantage (8x). On the other hand, some actors mentioned that water authorities did not stimulate firms to diffuse knowledge (6x). Water authorities are unwilling to pay for knowledge (3x), and they keep their requests broad/vague, which conflicts with the need for more concrete requests demanded by firms (4x).

Only two statements were made explicitly by the Wastewater Treatment sub-system. First, interviewees mentioned more need for collaboration on international/ EU-level to solve more significant challenges (3x). For example, an interviewee mentioned that the water authorities need to talk with shampoo producers about the size of the microbeads in their products. If the size of the beads could be increased, it would support the wastewater treatment (1 water authority). Secondly, some actors in the overall MIS mentioned that water authorities do not openly discuss their ideas on what a circular wastewater treatment should look like. This makes it hard for other actors to anticipate and make alterations up or downstream in the value chain (2x).

## *SF4A: Problem Directionality*

Interviewees scored SF4A with an average score of 2.65 (N=23), which is the second-lowest average score of all nine system functions. The highest average scores were given by the contractors (4.0). The lowest average scores were given by research institutes, waste disposal & recycling organizations, financial- and network organizations (all four actor types gave an average score of 2.0).

Despite the relatively low average score, a few strengths of the MIS regarding SF4A were mentioned. First, circularity has gotten more priority over the years (12x). Some employees of water authorities are intrinsically motivated to make the circular transition successful (4x). Contractors, water authorities, and Rijkswaterstaat also give some priority to circularity due to its (potential future) financial benefits (5x). Some interviewees mentioned the nitrogen crisis as an important factor that led to more urgency for the circular transition (3x). The aforementioned *'Ambitieweb'* (Chapter 4.1) was also identified as a valuable tool to force water authorities and firms to discuss the circular ambition in a project (and to combine multiple societal challenges) (3x).

Interviewees mentioned numerous weaknesses regarding SF4A. First, water authorities (and other governmental organizations) are not always proactive in the circular transition and do not give the topic a lot of priority (8x). Table 11 gives an overview of the reasons that were given and their frequency. Some of these reasons stand out and deserve further elaboration. Reason 1, the priority for financial expense, was rationalized by interviewees due to water authorities being afraid that circularity leads to an increase in tax for citizens, which they want to avoid (8x). In the Netherlands, every household pays its regional water authority a tax for its services (*waterschapsbelasting*). Investing in the circular transition could lead to a potential tax raise. Water authorities find it challenging to explain to the taxpayer why they should pay (more) for the circular transition and find it hard to make investments that are not directly connected to their core activities (7x).

Table 11: Overview of the reasons for low priority for circularity by water authorities (according to interviewees)

| Reason for low priority for circularity by water authorities | | Frequency |
|---|---|---|
| 1. | Financial expense gets more priority than circularity | 13x |
| 2. | Lack of priority given by the administration of a water authority/ large dependency on the priorities of the administration | 13x |
| 3. | Too much focus on core activities leads to less priority for circularity | 12x |
| 4. | Not yet clear what circularity is, how to assess and measure it, and what the concrete direction forward is | 10x |
| 5. | Necessity and benefits of circularity are not clear | 9x |
| 6. | Most employees are already busy with their own tasks and don't have time/ interest in circular transitions | 9x |
| 7. | Circularity is not enforced as a boundary condition to operate/ other societal challenges have more urgency | 7x |
| 8. | Water sector uses an efficiency approach which hampers the ability to be open for circular solutions | 3x |

Reason 2, the lack of priority given to circularity by the administration was explained by some actors as a result of short board terms (4 years) (3x) and the dependence on an opportunity to 'score' with circularity in public perception (3x).
Regarding the overall MIS, interviewees mentioned that non-governmental actors were not always proactive in the circular transition or did not give it a lot of priority (6x). Industrial buyers were not interested in a circular product if it costs more and/or had a lower quality (5x). Contractors and consultancy firms lacked pro-activity as they were not stimulated/assessed regarding circularity. Numerous interviewees mentioned that water authorities gave not enough financial incentive to make circularity a priority (10x).
The last category of weaknesses was related to both the Mission Arena and the overall MIS. Multiple trade-offs between different societal challenges were mentioned, which hamper the priority for circularity. As previously mentioned in the Problem-Solution diagnosis, circularity can stand in the way of other sustainability ambitions. Multiple actors mentioned a problematic trade-off between circularity and safety/ human & environmental health (10x). Similarly, actors noticed a trade-off between circularity and energy savings/emission (9x). Most interviewees mentioned that the latter gets priority over circularity (8x).

In terms of sub-innovation systems, only Wastewater Treatment mentioned one specific weakness. Two waste disposal & recycling organizations mentioned that the robustness of their systems and security of supply get priority over circular innovation (2x).

## *SF4B: Solution Directionality*

SF4B received an average score of 2.68 (N=19), the third-lowest average score of all nine system functions. The lowest average scores were given by regional water authorities, governmental organizations, and contractors (all three actor types gave the average score of 2.0). The highest average scores were given by financial organizations (4.0) and technology developers (3.5).

Several interviewees mentioned that there is some form of solution directionality in place to tackle the mission. Generally, circular solutions focus on extracting and re-using materials (4x). There is currently a significant focus on extracting and re-using materials from Wastewater Treatment (e.g., phosphate, cellulose, sewage sludge) (9x). Value retention of biomass is considered as well (3x). The EFGF is seen as an essential organization in giving direction for solutions (6x), as they prioritize specific materials for circular innovation (i.e., cellulose, Kaumera, bioplastics, struvite) (6x). Last, multiple actors mentioned that solution interdependency is recognized and exploited (6x).

Nevertheless, many weaknesses were mentioned regarding SF4B. The most frequent statement was that, although attempts are made, there is an apparent lack of solution directionality (18x). Multiple actors mentioned that it is still challenging to make choices regarding solution pathways (9x). Three reasons were given for the insufficient solution directionality by water authorities. First, it was mentioned numerous times that although there is a circular goal, there is a lack of understanding of how this goal should be reached (12x), based on a lack of knowledge on the subject (SF2) (9x) and a lack of understanding of the current position in the transition (SF4C) (4x). Secondly, a lack of overarching direction was mentioned, as regional water authorities all try to find their own solutions (3x), and circularity is implemented on a project level, but not on higher levels (5x). Third, non-Mission Arena actors mentioned that water authorities are not always open to discuss with firms which direction should be taken (7x), as decisions are made in the design phase without consultation by outsiders (4x).

An additional weakness is that solutions are primarily focused on making the core activities of water authorities circular instead of branching out to solutions that can have a more considerable societal impact (4x). Multiple interviewees mentioned that circularity was insufficiently approached from a larger societal perspective (7x) as (1) circularity was mostly micromanaged within projects (3x) and due to (2) a perceived difficulty in integrally combining societal challenges when proposing solutions (3x).

However, the most elaborate weakness in SF4B is the discussion regarding whether it is 'good' or 'bad' to choose specific solution pathways already. Actors seem to be split on whether the current lack of solution directionality provided by water authorities hampers the transition.

On the one hand, interviewees mentioned that it is preferred to have low directionality (11x). Actors mention that this phase is mostly about knowledge development and experimentation (9x) as it is helpful to spread chances and make sure that opportunities are not missed (6x). It was also mentioned that it is currently complicated to review which solutions are 'good' or 'bad' (4x). More time is needed to understand (1) what circularity is/ what its dimensions are (3x), (2) how circularity works in practice (4x), and (3) where impact is needed (3x).

On the other hand, numerous interviewees mention that it is a problem for other actors if the water authorities keep low solution directionality (9x). Some interviewees stated that they see it as a problem for their own organization (5x). The lack of SF4B makes it hard for non-Mission Arena actors to anticipate and/or make investments for a circular transition (4x). Others mentioned that assets in the water sector (e.g., treatment plants, flood defenses, waste incinerators) have long lifespans, which makes a 30-year transition not as long as it seems. According to them, the timing of the transformation is insufficiently considered (4x). On a more abstract level, interviewees mentioned their disagreement with the method of creating directionality. Instead of waiting for more clarity, they recommend making choices and reflecting on the results to make alterations during the process (i.e., using the Deming-cycle) (4x).

In terms of sub-innovation systems, two statements were made. First, in line with the results of the Problem-Solution diagnosis, interviewees mention that solutions are mainly created from a technological perspective instead of a social perspective and that the focus is mainly on the re-use of materials from Wastewater Treatment (3x). Second, two actors in the Flood Defenses sub-system mentioned a lack of direction regarding the level of circularity that solutions should adhere to (2x). This weakness is related to the lack of a circular hierarchy for soil and dredged material mentioned in SF2.

## *SF4C: Reflexive Governance*

SF4C scored an average of 2.32 (N=22), the lowest average score of all nine system functions. In total, five interviewees scored this SF with a 1.0. The lowest average scores were given by regional water authorities (1.25) and waste disposal and recycling organizations (1.50). The highest average scores were given by financial organizations (4.0) and contractors (4.0).

Despite the low average score, a few strengths regarding SF4C were mentioned. First, steps are being taken to create material flow analyses and monitor material flows (8x). Monitoring was already being done for emissions in the '*Klimaat Monitor'* (Climate Monitor, the dominant tool for water authorities to assess their environmental impact) (3x), and recently circularity was added to this tool (4x). The Dutch Water Authorities is seen as the actor that takes the leading role regarding monitoring (6x).

However, multiple weaknesses were brought up with high frequency. Overall, interviewees mentioned a lack of reflection (15x) and a lack of adjustment/ corrective measures (7x). Numerous actors noticed a lack of insight into the impact/ efficiency of the circular activities performed, making it hard to anticipate and to choose between alternative solution pathways (SF4B) (10x).
Additionally, a lack of monitoring on circularity was mentioned (i.e., how materials are produced, where they are sourced, and the level of value retention) (10x). The lack of monitoring has multiple reasons, according to actors. First, there is a lack of understanding of how circularity should be monitored (i.e., what indicators should be used) (12x) because of unclear dimensions of circularity (7x) and a lack of specific goals that give direction for monitoring (SF4B) (6x). (4x). Secondly, it is still unclear which instrument should be used for monitoring (3x), which can be problematic as a lack of uniformity makes it difficult to compare and learn (3x). Third, data is insufficiently available (4x). However, it was notably mentioned that one actor type did not have these problems. Contractors that used soil and dredged material (Flood Defenses & Water Level sub-systems) used a very optimized monitoring system regarding circularity. There is a financial incentive for them to know exactly which materials they used (4x). However, water authorities did not seem to ask the contractors about their available data (3x).

In terms of sub-innovation systems, one specific weakness was apparent. Two actors in Wastewater Treatment mentioned that water authorities monitor only a part of the value chain. Water authorities are not fully aware of the available data before and after their wastewater treatment process (2x).

## *SF5: Market formation and destabilization*

Interviewees scored SF5 with an average score of 2.76 (N=21), which is the fifth-highest average score of all nine system functions. The highest average score was a 3.0, given by six actor types. The lowest average score was given by consultancy & engineering firms (2.33). SF5 is, therefore, the system function with the lowest deviation between scores.

In total, only a few strengths of SF5 were mentioned. Interviews noticed that many pilot projects are initiated (10x). Water authorities try to be open to implementing circular innovations (i.e. being a launching customer) (9x) and support scale-up (e.g. PHARIO, Kaumera) (10x). Additionally, the firm AquaMinerals supports water authorities in finding industrial buyers willing to use the circular materials (3x).

However, many of the weaknesses directly contradict these strengths. First, several interviewees mention a lack of market formation and insufficient support for upscaling circular innovations by water authorities (10x). Multiple underlying reasons were given. (1) Water authorities choose the cheapest option, find circularity too expensive, and are not committed to paying the true price (8x). (2) The investment in circularity is perceived as too financially risky (7x). Furthermore, (3) there is a lack of urgency for change (4x). Actors also mentioned that (4) insufficient volume/mass/ uniformity (3x) and (5) fragmented budgets do not give opportunity for investing in circular innovation (4x). Some posed the lack of SF5 as (6) a failure of the general financial system (i.e., costs are not internalized, the true price is not paid, lack of tax on virgin materials) (5x). Last, multiple interviewees mentioned that (similar to SF1 & SF3) that water authorities do not stimulate firms due to a lack of clear/ ambitious

inquiry (9x). Water authorities have made impactful project decisions before discussing with firms, which reduces the room for implementing effective circular innovation (4x).
Second, it was mentioned that firms in the overall MIS also insufficiently supported the market formation and scale-up of circular innovations (5x). Working in a circular way is still seen as very dependent on intrinsic motivation (3x). Firms are not (financially) stimulated to operate circular (8x) and perceive it as too risky/ without guaranteed future benefits (3x).
Third, a lack of demand by industrial buyers for circular materials (e.g., cellulose from wastewater) was mentioned (4x). Buyers were not (financially) stimulated to buy these materials (5x) as the quality (3x) and volume (3x) were perceived as insufficient.
Fourth, innovations keep stuck in the pilot phase and are not able to scale up (14x). Multiple reasons were given, which are mentioned in Table 12. Reason 1, 'insufficient investment capital allocation' is further elaborated on in SF6.

Table 12: Overview of the reasons why circular innovations keep stuck in a pilot phase (according to interviewees)

| **Reasons why circular innovations keep stuck in a pilot phase** | | **Frequency** |
|---|---|---|
| 1. | Insufficient investment capital allocated for scale-up/ scale-up is seen as too expensive/ lack of a proper value case | 12x |
| 2. | Insufficient volume of the right quality at the right moment | 6x |
| 3. | Obstruction of circular technologies/ products by regulation | 4x |
| 4. | Discussion about distribution of income, expense and risk between partners hinders the process | 3x |
| 5. | Lack of persistence by regional water authorities | 3x |
| 6. | Collaboration by partners is hindered by tendering legislation | 3x |

For each sub-innovation system, specific statements were made regarding market destabilization. Actors mentioned an overall lack of phasing out technologies/ practices harmful to the mission (8x). Regarding Water Level, it was mentioned that it is challenging to implement new circular solutions for dominant materials (e.g., tropical hardwood) (2x). Actors within Flood Defenses mentioned that regulation hinders the ability to phase out low-quality material re-cycling (2x). An interviewee mentioned: *"I think that a small bit of regulation should be changed. Currently, we can't re-cycle our soil and dredged material to prevent subsidence. (. . .) This has to do with quality. Dredged material that is released during a project is slightly contaminated. This means that you can't use it to raise a meadow or an industrial area [high-level re-cycling]. So, what happens? The material is used to build a noise barrier, green bridges, or to shallow a sand extraction pond [low-quality re-cycling]. I'm sure that we can do this differently."* (1 waste disposal & recycling organization, translated from Dutch). Last, interviewees from the Wastewater Treatment sub-system mentioned that it is hard to 'stop' wastewater treatment technologies, to implement something new, as continuity is very important (3x). Additionally, alternative technologies are not far enough developed to be implemented (e.g., alternatives for sewage sludge incineration) (2x).

## *SF6: Resource (re)allocation*

Interviewees scored SF6 with an average score of 2.70 (N=20), the fourth-lowest average score of all nine system functions. The lowest average scores were given by network organizations (1.0), and the highest scores were given by waste disposal & recycling organizations (4.0). Overall, interviewees made the least number of unique statements on this SF.

A small number of strengths were mentioned regarding Resources (re)allocation. First, interviewees mentioned that water authorities mobilize many financial resources for circular innovation (6x). Other MIS actors support financially as well. The *Water Innovatiefonds* opens the possibility to mobilize resources towards the development and scale-up of circular innovation (3x). Subsidies are also made available to limit the financial risk of circular innovation (3x). Last, firms heavily invest financial resources in circularity to win tenders or due to perceived future (financial) benefit (5x).

However, like SF5, many of the weaknesses directly contradict these strengths. Numerous actors mentioned that water authorities insufficiently mobilize financial resources for circularity (11x). Many different reasons were given for this lack of mobilization, which can be found in Table 13. As the table shows, this SF6 weakness results from multiple previously mentioned weaknesses, mostly from SF4A & SF4B. This is further illustrated in the Systemic Barrier Analysis (Chapter 4.4).

Table 13: Overview of the reasons for low financial resource mobilization by water authorities (according to interviewees)

| Reasons for low financial resource mobilization by regional water authorities | | Frequency |
|---|---|---|
| 1. | Circularity is not placed high on the agenda/ does not have a high priority | 8x |
| 2. | Water authorities do not want to raise tax/ Difficult to explain taxpayer | 7x |
| 3. | Circularity is seen as too expensive | 6x |
| 4. | Investment in circularity is seen as too risky | 6x |
| 5. | Lack of strategy/direction makes it hard to allocate financial resources | 4x |
| 6. | Large focus of core activities makes it hard to allocate for circularity | 3x |
| 7. | Administrations do not give a high priority to circularity | 3x |
| 8. | Budget is fragmented over multiple projects | 3x |
| 9. | Future benefits are difficult to measure | 3x |
| 10. | Financers (e.g. banks) find the investment too risky (especially TRL 7) | 3x |

Furthermore, a few interviewees mentioned that it was difficult for water authorities to find internal FTEs/capacity to work on circularity (5x), primarily due to a lack of priority for the topic (3x).
Last, it was mentioned that firms also find it challenging to mobilize financial resources for circularity (5x). Entrepreneurs find the investment too risky or the benefits too low (4x). Additionally, circularity was seen as too expensive, and most of the time, the cheapest option was chosen (4x).

There were no statements made that were specific to any sub-innovation system.

## *SF7: Creation and withdrawal of legitimacy*

Actors scored SF7 with an average score of 2.88 (N=16), which is the third-highest average of all nine system functions. The highest average scores were given by the network organizations (4.0) and waste disposal & recycling organizations (4.0). The lowest average scores were given by regional water authorities (1.67) and financial organizations (2.0).

Multiple strengths were mentioned regarding SF7. Interviewees mentioned that water authorities and Rijkswaterstaat start to find circularity more essential and give it more legitimacy (9x). Still, necessary efforts are undertaken to create legitimacy for circularity (6x). Actors mentioned that the Dutch Water Authorities and regional water authorities attempted to create legitimacy by (1) having some colleagues that claim the legitimacy of circularity within the organization (3x), (2) giving impulses to water authority administrations to give more priority to circularity (5x), and (3) lobbying for the relaxation of regulation to use materials in a circular way (nationally and on a European level) (5x).

Multiple weaknesses were mentioned regarding SF7. Remarkably, some interviewees felt that removing resistance is unnecessary and a waste of time (3x). Overall, a lack of creation of legitimacy (5x) was noticed. Statements were made about the legitimacy of circularity within water authorities, firms, and the public perception.
Regarding water authorities, interviewees mentioned an overall lack of motivating/ directing/ judging employees to work in a circular way (11x). Actors noticed that some water authorities lacked an administration that legitimized circularity within their organization (5x). Furthermore, interviewees

mentioned a lack of effort by employees and other MIS actors to make administrations legitimize circularity (4x).
Interviews mentioned insufficient effort by MIS actors to make firms supportive of material re-use and contributors to a CE (4x). Some actors noticed that the Mission Arena lacks understanding of what the value chain looks like and how to shape them for a circular economy (3x).
Furthermore, interviewees mention a lack of legitimacy creation by MIS actors to make the public supportive of the re-use of materials/ circularity in general (6x). Documentaries/ social media negatively shape the public opinion on circularity, which hampers the circular transition (3x). Multiple actors mentioned the example of '*De Vuilnisman*'; a Dutch documentary on circularity that aired during the interviews. This documentary exposed the negative side effects of a CE, such as financial fraud and harmful environmental practices (van de Keuken, 2021). An interviewee mentioned: *"There is a lot of social resistance regarding circular applications and material re-use. I'm not sure if you watched 'de Vuilnisman'? (. . .) That really does not help."* (1 waste disposal & recycling organization, translated from Dutch). In regard to regulation, multiple actors mention that this is a limiting factor in this circular transition (e.g. regulation on PFAS) (11x). Lobbying for the relaxation of regulation regarding circular usage of materials (i.e. getting the *'einde afval status'* predicate for circular materials) has not led to many changes yet and/or is going slow (6x). As an explanation, it was mentioned that there is a lot of resistance for re-using material out of safety reasons, which leads to slow and careful consideration by regulatory bodies (8x). Remarkably, there was no consensus between MIS actors on the need to change regulation. Some actors were in favor of altering regulation (3x), while others were in favor of the current regulation and its 'better safe than sorry' methods (3x).

Regarding sub-innovation systems, one statement was made. Actors from Wastewater Treatment mentioned that the government/ politics prioritize challenges regarding energy, emission, and micropollutants. This makes it hard to create legitimacy for circularity (2x).

# 4.4 Systemic Barriers Analysis

The weaknesses per SF that were identified in chapter 4.3 were further analyzed on underlying root causes. Based on the interview data, many systemic weaknesses appear (indirectly) related. By connecting these relationships, a densely interconnected network of systemic weaknesses and root causes was established. Figure 4 gives an overview of all relations that have been found. This visualization shows which systemic weaknesses are part of the MIS Arena and overall MIS and how they are connected. The systemic weaknesses within the green circle originate and take place in the Mission Arena. The systemic weaknesses on the border of the green circle take place during the interaction between the Mission Arena and overall MIS. The systemic weaknesses on the white space are part of the overall MIS.

The figure can be split up into 5 'clusters' with systemic barriers, which are discussed in the paragraphs below. These clusters center around specific systemic weaknesses, which are deemed as ‘junctions’. These junctions are the result of multiple root causes. Most of these junctions also act as (one of) the primary cause(s) for the central systemic weakness (i.e., junction) in another cluster. Figure 5 is a simplified representation of Figure 4 and points out the location of the five junctions:

- Junction 1 is a lack of solution directionality by the Mission Arena (SF4B)
- Junction 2 is a lack of pro-activity in/ priority for the circular transition by regional water authorities (SF4A)
- Junction 3 is the difficulty for water authorities to mobilize financial resources for circularity (SF6)
- Junction 4 regards the notion that innovations keep stuck in the pilot phase and their inability to scale up (SF5)
- Junction 5 regards the different philosophies on knowledge diffusion between water authorities and contractors/ consultancy firms (SF3)

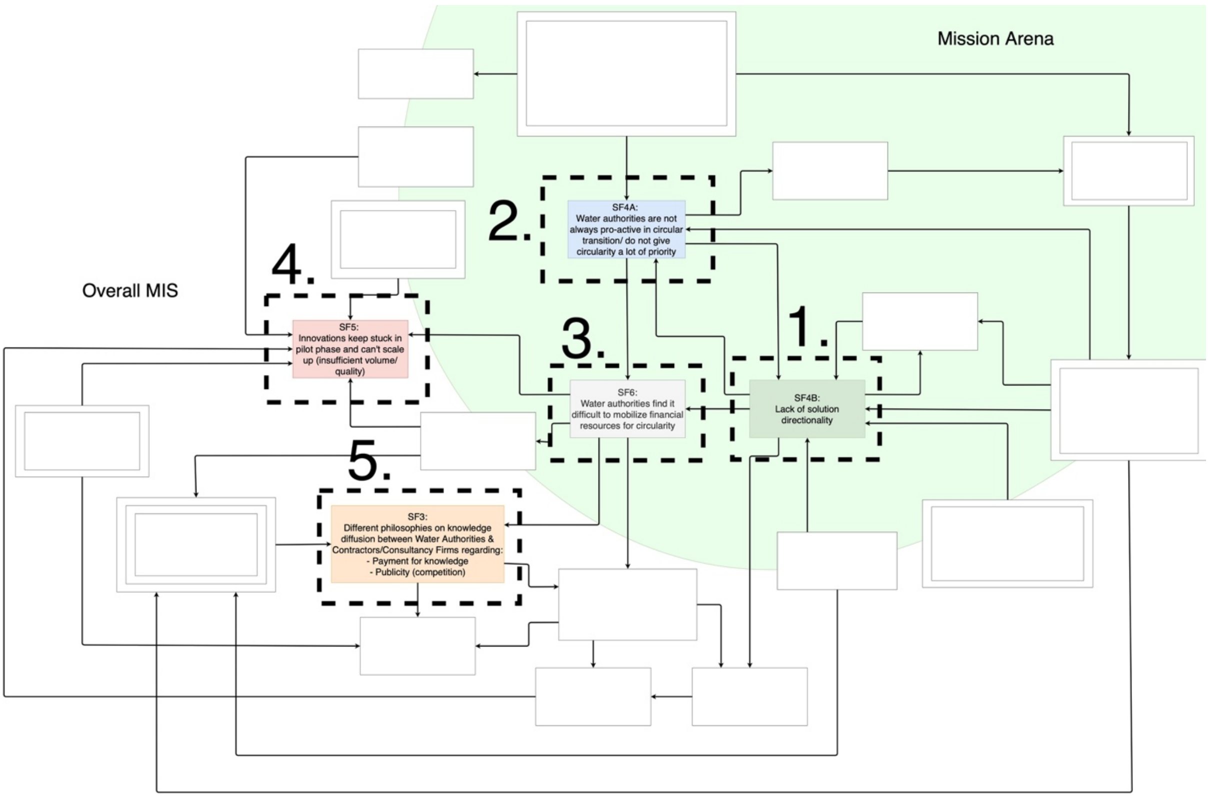


Figure 5: Simplified representation of Figure 4. Displays the location of the 5 ‘junctions’ in the network of barriers

### 4.4.1 General overview of the Systemic Barriers

Based on the overview in Figure 4, a few essential overarching statements can be made. First, the lack of knowledge regarding what a CE is and how to assess/ measure it (SF2 & SF4C) have been indicated as the most critical root causes for Junctions 1 & 2. Second, the lack of solution directionality (SF4B) and problem directionality (SF4A) for circularity are the main reasons that make it difficult for water authorities to mobilize financial resources for the achievement of the mission (SF6). Third, the lack of financial resource mobilization (SF6) is the main 'bridge' between the systemic weaknesses in the MIS Arena and the overall MIS. This weakness can be seen as an important root cause for Junctions 4 & 5. Fourth, Junction 4 is one of the most impactful barriers in the network. As pilots cannot scale up (SF5), the development and diffusion of innovation are hampered. This impacts the ability to achieve swift mission success. Fifth, Junction 5 is one of the most latent barriers in the network. However, this barrier is detrimental for understanding the lack of priority and pro-activity by firms in the MIS.

### 4.4.2 Systemic Barrier Cluster 1: Lack of solution directionality

The first cluster centers around a lack of solution directionality. As mentioned in chapter 4.3, the Mission Arena has difficulty selecting solution pathways that should be used to transition towards circular water authorities.

Interviewees mentioned multiple root causes why SF4B was weakly fulfilled. First, there is a lack of knowledge within the MIS regarding the definition of circularity, what a CE should look like, and how it should be implemented within the organization (SF2, 9x). Secondly, the current situation regarding circularity is not mapped out/ monitored, making it hard to make choices regarding solution pathways (SF4C, 4x). This creates a lock-in between SF4B and SF4C, as monitoring also becomes more difficult without solution pathways to focus on (6x). Third, as described in chapter 4.3, there is a vigorous discussion between actors regarding whether it is 'good' or 'bad' that there is a lack of solution directionality. Many actors believe that it is okay to keep as many solution pathways open as possible (11x), preserving weak SF4B fulfillment. Fourth, water authorities are not always receptive to discussion with non-Mission Arena actors about which direction should be taken (SF3/SF4B, 6x). This is most visible in strict/ indisputable project descriptions in tenders (3x) and fear to show favoritism towards certain firms (3x). Last, water authorities give low priority to circularity, which leads to a lack of urgency to create direction for solution pathways (SF4A, 3x).

The lack of solution directionality has three main implications on other SFs. First, the lack of solution directionality leads to a lack of priority for circularity within water authorities (SF4A) (7x). This creates a lock-in between SF4A & SF4B. Second, water authorities find it challenging to mobilize financial resources for circularity if there is a lack of direction based on which resources can be allocated (SF6, 4x). Similarly, firms find it hard to anticipate/ invest when the Mission Arena lacks proper solution directionality (SF6, 4x).

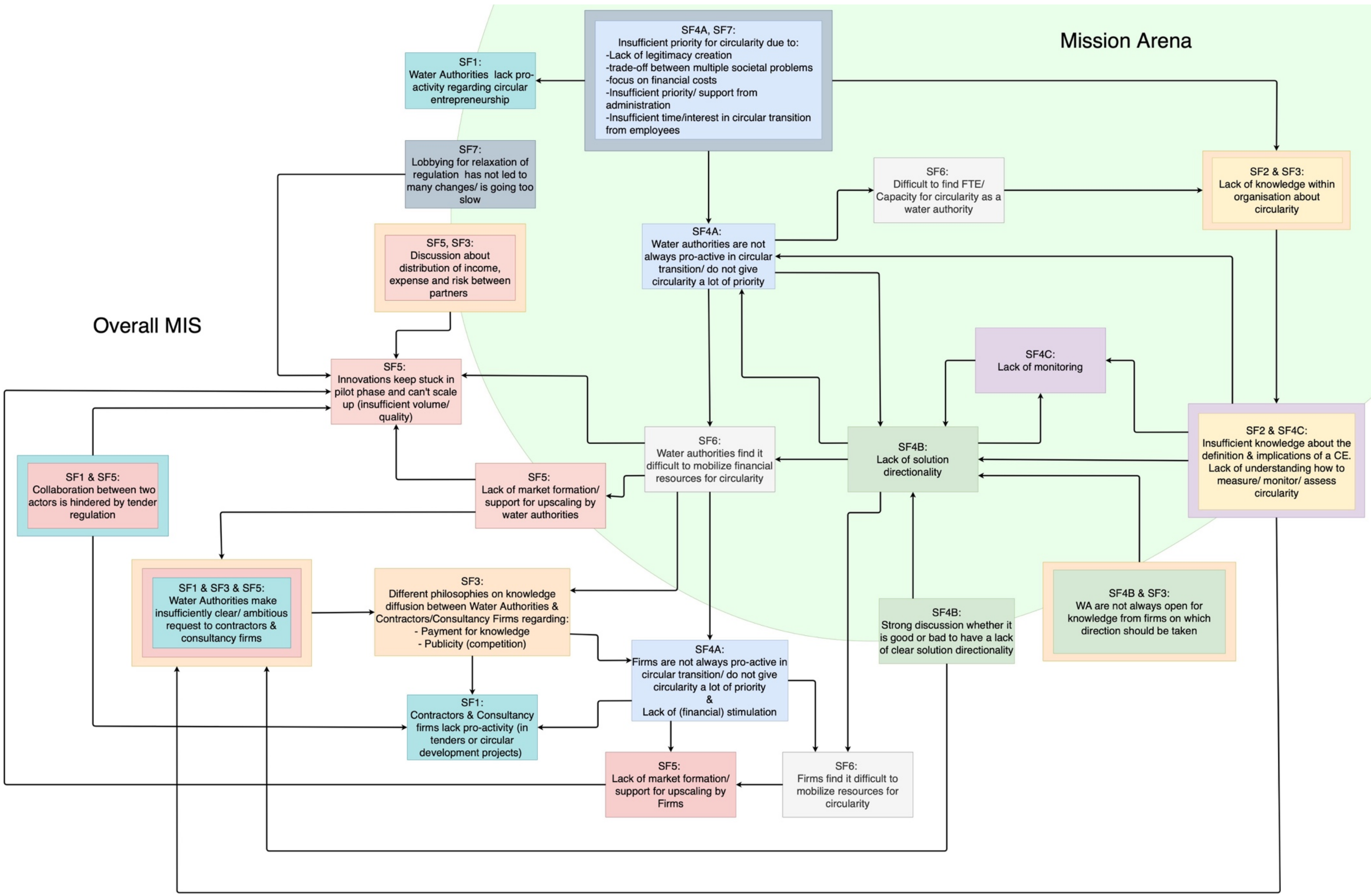
Mission Arena
Overall MIS
SF4A, SF7:
Insufficient priority for circularity due to:
-Lack of legitimacy creation
-trade-off between multiple societal problems
-focus on financial costs
-Insufficient priority/ support from administration
-Insufficient time/interest in circular transition from employees
SF1:
Water Authorities lack pro-activity regarding circular entrepreneurship
SF7:
Lobbying for relaxation of regulation has not led to many changes/ is going too slow
SF5, SF3:
Discussion about distribution of income, expense and risk between partners
SF4A:
Water authorities are not always pro-active in circular transition/ do not give circularity a lot of priority
SF6:
Difficult to find FTE/ Capacity for circularity as a water authority
SF2 & SF3:
Lack of knowledge within organisation about circularity
SF4C:
Lack of monitoring
SF5:
Innovations keep stuck in pilot phase and can't scale up (insufficient volume/ quality)
SF6:
Water authorities find it difficult to mobilize financial resources for circularity
SF4B:
Lack of solution directionality
SF2 & SF4C:
Insufficient knowledge about the definition & implications of a CE. Lack of understanding how to measure/ monitor/ assess circularity
SF1 & SF5:
Collaboration between two actors is hindered by tender regulation
SF5:
Lack of market formation/ support for upscaling by water authorities
SF1 & SF3 & SF5:
Water Authorities make insufficiently clear/ ambitious request to contractors & consultancy firms
SF3:
Different philosophies on knowledge diffusion between Water Authorities & Contractors/Consultancy Firms regarding:
- Payment for knowledge
- Publicity (competition)
SF4B:
Strong discussion whether it is good or bad to have a lack of clear solution directionality
SF4B & SF3:
WA are not always open for knowledge from firms on which direction should be taken
SF4A:
Firms are not always pro-active in circular transition/ do not give circularity a lot of priority
&
Lack of (financial) stimulation
SF1:
Contractors & Consultancy firms lack pro-activity (in tenders or circular development projects)
SF5:
Lack of market formation/ support for upscaling by Firms
SF6:
Firms find it difficult to mobilize resources for circularity

Figure 4: Representation of the interconnected network of barriers present in the MIS. Each square depicts a weakness that has been identified in Chapter 4.3. The arrows between the squares depict the causality. Each square color represents a system function: jade (SF1), yellow (SF2), orange (SF3), blue (SF4A), green (SF4B), purple (SF4C), red (SF5), grey (SF6), anthracite (SF7)

### 4.4.3 Systemic Barrier Cluster 2: Lack of priority for circularity by water authorities

The second cluster centers around the lack of priority that circularity receives from water authorities.

Multiple root causes were mentioned for the lack of priority. First, multiple interviewees mentioned a combination of insufficient knowledge regarding what circularity entails, how it should be assessed, and what the concrete direction forward is (SF2, SF4C, SF4B 10x). Second, actors mention a lack of legitimacy for circularity within water authorities (SF7). There is a lack of legitimacy creation by employees and other MIS actors to make circularity a priority within the administration (SF7, 4x). Some water authorities lack an administration that creates legitimacy within the organization (SF7, 5x) or gives priority to circularity in decision making (SF4A, 13x). Overall, several actors mention a lack of motivating, directing, and/or judging employees to work in a circular manner (SF7, 11x). Employees are busy with their tasks and do not have time/ interest in the circular transition (SF4A, 9x). Other root causes were related to activities/societal challenges perceived to deserve more priority than circularity: (1) Water authorities are fixated on their three core activities (SF4A, 12x). (2) There is difficulty in choosing which societal problems deserve more importance (SF4A, 6x) due to trade-offs between circularity and energy savings/emission (SF4A, 9x) and human health/ environmental impact (SF4A, 10x). (3) Financial costs seem to get more priority than circularity (SF4A, 13x).

Lack of problem directionality regarding circularity has four main implications on other SFs. First, as mentioned in 4.4.2, the lack of SF4A results in a lack of solution directionality (SF4B, 3x). Second, as a result of a significant focus on the core activities (4x) and the dependence on the priorities of the administration (9x), water authorities lack pro-activity regarding circular entrepreneurship (SF1). Third, a lack of priority makes it hard for water authorities to allocate capacity in the form of human resources (FTE) towards the circular transition (SF6, 3x). The last implication of a lack of SF4A is that water authorities find it difficult to mobilize financial resources towards the circular transition (SF6, 8x).

### 4.4.4 Systemic Barrier Cluster 3: Water authorities have difficulty to mobilize financial resources for circularity

The third cluster is centered around the difficulty for water authorities to mobilize financial resources for circularity. This cluster forms the main bridge between the systemic barriers in the MIS Arena (Cluster 1 & 2) and the barriers found in the overall MIS (Cluster 4 & 5).

As mentioned in chapters 4.4.2 & 4.4.3, water authorities find it challenging to mobilize financial resources towards the circular transition (SF6, 12x) for two reasons. First, due to insufficient solution directionality (SF4B) and its root causes described in Cluster 1. The lack of direction makes it hard to allocate financial resources (SF4B, 4x). Second, due to a lack of priority for circularity (SF4A) described in Cluster 2. Specifically due to a lack of priority by the water authority administrations (SF4A, 3x), the significant focus on core activities (3x), the perceived expensiveness of circularity (6x), and the difficulty to explain the investment to taxpayers (7x).

The lack of resource mobilization has implications for four other systemic weaknesses. First, due to the insufficient allocation of investment capital, innovations keep stuck in a pilot phase and cannot scale up (SF5, 12x). Second, low resource mobilization negatively affects the abilities of water authorities for market formation and scale-up support (SF5, 7x). Third, water authorities are unwilling to pay for the diffusion of knowledge by firms (SF3, 3x), which affects their pro-activity (explained in Cluster 5). Fourth, the lack of resource mobilization does not (financially) stimulate firms to give priority to circularity (SF4A, 10x).

### 4.4.5 Systemic Barrier Cluster 4: Innovations keep stuck at pilot phase and cannot scale up

The fourth cluster centers around the inability of pilots to scale up (SF5, 14x). This is an impactful weakness and has root causes in the Mission Arena and the overall MIS.

In total, six root causes hamper the scale-up of circular pilots. First, interviewees mentioned that insufficient capital is allocated for scale-up/ scale-up is perceived as too expensive (SF6, 12x). Secondly, there is insufficient market formation and support for upscaling by water authorities (SF5, 10x). Several actors mentioned that water authorities could act even more regularly as launching customers or be open for innovations with a low TRL level (SF5, 5x). Likewise, there is also a lack of market formation and upscaling support by firms (SF5, 5x). Fourth, discussion about the distribution of income, expense, and risk between partners hinders the scale-up process (SF5, 3x) as partners believe that there is an unfair distribution between costs and benefits (SF3, 4x). The last two root causes are legislative. Regulation obstructs the circular (re)use of materials (SF7, 11x), and lobbying for relaxation has not led to many changes/ is going too slow (SF7, 6x). Similarly, tendering regulation makes it difficult to start collaborations between actors (SF5, 3x), which hampers the ability to gain the necessary volume/mass to scale up (SF5, 4x).

### 4.4.6 Systemic Barrier Cluster 5: Different philosophies regarding knowledge diffusion between water authorities and contractors/ consultancy firms

The final cluster centers around the different 'philosophies' regarding knowledge diffusion between multiple MIS actors (SF3, 7x). The 'Knowledge Diffusion' section (SF3) in Chapter 4.3 described the different lines of thought between water authorities and contractors/ consultancy firms. It showed that (1) there is an ongoing discussion on payment for knowledge, and (2) that fear of competition leads to a 'wait and see' attitude from firms. This section discusses the root causes for this discrepancy and how it affects other systemic weaknesses.

The disagreement in knowledge diffusion has two root causes. It partly originates from a lack of resource mobilization (SF6), as water authorities are hesitant to pay firms purely for sharing their knowledge (SF3, 3x). Secondly, water authorities make insufficiently clear/ ambitious requests to contractors & consultancy firms (SF1, SF3, SF5). As explained in chapter 4.3 (SF1), this results in a situation in which firms wait for a water authority to make a more concrete request, as they are afraid to ‘price themselves out of the market’. The underlying reasons for the unclear/ unambitious requests are: (1) a lack of knowledge of what a circular water authority should look like (SF2, 4x), (2) water authorities want to keep multiple options open (SF4B, 6x), and (3) water authorities give a small room for input from firms in tenders (SF5, 4x).

The discrepancy regarding knowledge diffusion has multiple (indirect) effects. First, as water authorities are hesitant to pay firms purely for sharing their knowledge (SF3, 3x), firms lack an incentive to incorporate circularity in their operations (SF4A, 10x). This has an indirect negative effect on pilot upscaling (SF5) through a lack of resource mobilization (SF6, 5x) & market formation (SF5, 5x) by firms. Secondly, the discrepancy directly affects the proactivity of firms in tenders & circular projects (SF1) because contractors and consultancy firms do not want to share their ideas. They 'keep their cards close to their chest' due to the fear of competitors copying their ideas. Therefore, these firms wait for water authorities to make a more concrete inquiry (SF1, 5x).

# 4.5 Reflection on (planned) governance actions

As stated in the previous chapter, there are 5 clusters of barriers and weaknesses. This chapter discusses the (planned) governance actions by the Mission Arena to address these barriers to support a swift achievement of the mission. Furthermore, it describes the 'blind spots' in the current set of actions. As explained in the methodology, the policy document 'The story of Circular Water Authorities' (*Het verhaal van de Circulaire Waterschappen*) was used during this analysis (Nanninga & Glas, 2021).

## 4.5.1 Identified governance actions

According to the policy document, the MIS Arena identified six policy foci (*transitielijnen*) that should support the transition towards circular water authorities. Each focus consists of multiple actions, which act as operationalizations. Table 14 gives a brief description of the policy foci, the number of governance actions per foci, and how many identified barriers are addressed. The table shows that, in total, 42 out of 90 actions are relevant to the weaknesses & barriers in Chapter 4.4. The other 48 actions supported the circular transition but did not address an identified barrier (e.g., 'creation of endurance', 'collaboration with other sectors', 'education on transition management').

Table 14: Overview and description of the policy foci in Nanninga & Glas (2021) and number of governance actions that address weaknesses & barriers identified in Chapter 4.3 & 4.4

| **Policy foci** | **Description** | **Number of governance actions mentioned per policy foci** | **Number of governance actions that address identified weaknesses & barriers** |
|---|---|---|---|
| Sustainable Commissioning | Implementing 'Sustainable Commissioning' as a new method for embedding sustainability (and circularity) in internal and external commissions done by water authorities. | 14 | 5 |
| Circular Asset Management | Aligning the assets of a water authority with its circular goals, with a focus on re-use and extending the lifespan. | 11 | 4 |
| Retrieval of Energy & Resources | Retrieving energy and resources from the core activities of water authorities and optimizing the system to do so. | 17 | 10 |
| Transition Management | Educate employees of water authorities on transition management and learn from other societal transitions. | 16 | 6 |
| Organizational- & Behavioral Change | Make circularity part of how the employees of water authorities work, think and act. Circularity becomes part of the core activities, not an extra activity. | 22 | 11 |
| Collaboration | Creating collaborations between organizations (inside and outside the value chain) to develop and strengthen the circular economy. | 10 | 6 |
| | Total: | 90 | 42 |

All 42 governance actions that address a barrier mentioned in Chapter 4.4 are shown in Table 15. In total, the 42 systemic instruments address ten barriers.

Of the 42 governance actions, 19 addressed root causes for the lack of solution directionality (SF4B, junction 1). Overall, these actions focus on three root causes. First, it focuses on the lack of knowledge regarding circularity (SF2) by increasing education and learning capabilities by sharing knowledge and experiences. Second, it addresses the lack of monitoring by embedding material and resource flow analyses in the processes of water authorities (SF4C). Third, it attempts to end the dispute regarding whether it is 'good' or 'bad' to have low solution directionality (SF4B). While these governance actions do not 'solve' this discussion, they provide pathways forward by evaluating pilots that should be scaled up, to prevent initiating too many pilots without looking at scale-up potential. It also tries to create a balance between strict solution directionality and room for circular initiatives.

Twenty-nine governance actions address the root causes for the lack of priority for circularity by water authorities (SF4A, junction 2). Sixteen of these actions overlap with junction 1, as both address the root causes 'lack of knowledge' and 'lack of monitoring' (SF2 & SF4C). The other 13 instruments address specific reasons for low SF4A fulfillment. First, it addresses the insufficient time/ interest in the circular transition from employees (SF4A) by raising awareness and combining circular ambitions with the employees' motives. Second, the heavy focus on core activities, other societal challenges, and financial costs over circularity (SF4A) are addressed. (1) By providing insight into the 'true' societal costs & benefits, and (2) by embedding circularity in daily processes. Third, the insufficient priority/ support for circularity by administrations (SF4A, SF7) is addressed by ensuring that (1) circularity gets more importance on the agenda and (2) that long-term circular investments cannot be delayed. Additionally, governance action is taken to make administrations motivate their employees.

Three actions were identified that address the root causes of the difficulty for pilots to scale up (SF5, Junction 4). The slow process of lobbying for the relaxation of the regulation (SF7) is addressed. First, by intensifying current practices to remove juridical barriers (while respecting the reason for the initial juridical protection, e.g., human health). Second, by following and influencing the political developments on $CO_2$ pricing and the taxation usage of virgin materials.

Six actions were related to barriers found in Cluster 5. Two actions were related to the insufficiently clear/ ambitious requests by water authorities to contractors & consultancy firms (SF1, SF3 & SF5), resulting in discrepancies in philosophies on knowledge diffusion (SF3, Junction 5). These were addressed through (1) more straightforward descriptions of the circular goals that water authorities have in internal & external inquiries, and (2) by incentivizing contractors/firms to provide circular added value to the water authorities (e.g., by providing a value-case instead of a business case). The other four actions were related to the lack of priority for circularity by firms (SF4A), resulting in a lack of proactivity in tenders and circular projects (SF1). This barrier was addressed through increased collaboration and alignment of ambitions.

### 4.5.2 Blind spots and governance action recommendations

The governance actions set by the MIS Arena address numerous root causes of the systemic weaknesses in the innovation system. However, some root causes were just partly addressed, while others were completely neglected. These 'blind spots' will be discussed in combination with relevant policy recommendations. (N.B. There were no policy instruments identified that perpetuated or reinforced the barriers.)

A few root causes were not mentioned in the policy document. First, water authorities are not always receptive to knowledge from firms on which direction should be taken (SF3 & SF4B), resulting in a lack of solution directionality (SF4B). The current Mission Arena does not represent any non-governmental actor types in general. Therefore, it is recommended that water authorities consult/involve firms on solution directionality. A similar recommendation was made by 2 interviewees (1 contractor, 1 technology developer).

The second root cause that was not addressed in policy is the ongoing discussion about the income distribution, expense & risk during collaboration (SF3 & SF5). As this directly hampers the scale-up of pilots (and therefore the achievement of the mission), it is recommended to address this barrier. Interviewees mentioned multiple solutions that can be translated into governance actions, such as: (1) increased dialogue between partners in order to gain trust, (2) grant partners their benefit of the collaboration, and (3) fair distribution of profit based on what parties bring to the table in terms of e.g. innovations, volume and capital (1 technology developer, 1 research institute, 1 financial organization).

Multiple root causes were partly addressed. First, the policy actions address the insufficient knowledge on circularity (SF2) in order to make decisions in solution directionality (SF4B) and give more priority to circularity (SF4A). However, these actions are primarily focused on increasing education and learning capabilities. While these instruments are helpful, they lack insight on the specific lacunae in the knowledge that should be addressed. It is recommended to create a concrete R&D agenda that states which knowledge gaps have to be targeted. Based on the SF2 results in chapter 4.3, these questions should be related to (1) what a circular economy should look like and (2) how it can be implemented in daily work processes. A similar recommendation was given by one interviewee (1 water authority).

Second, multiple governance actions address the lack of monitoring (SF4C), negatively affecting problem and solution directionality (SF4A & SF4B). However, these actions seem to be entirely written from the perspective of the water authorities. In chapter 4.3 (section SF4C), it was notably mentioned that contractors (from the Flood Defenses & Water Level sub-innovation system) monitored circularity of materials well due to financial benefits for them to know which exact materials they used. It is recommended that this expertise and data is used for the achievement of the mission. Governance action can be taken to (1) transfer knowledge to other sub-innovation systems, (2) use data gathered by contractors to analyze the progress of the mission, and (3) identify if monitoring can be incentivized (as contractors monitor due to a financial incentive).

Third, only two actions have been identified that addresses the trade-off between multiple societal challenges (SF4A) that results in a lack of priority for circularity (SF4A) (Table 15, action 27 & 31). As circularity is supposed to be a tool to support achieving sustainability (instead of hampering it), the least number of trade-offs should be created. It is recommended to create an assessment framework that incorporates several different societal challenges and identifies synergies (instead of choosing one societal challenge over the other). These policy recommendations align with statements by multiple interviewees (2 water authorities, 1 waste disposal & recycling company), who specifically recommended the Donut Economy model (Raworth, 2017) and the societal cost-benefit analysis as potential frameworks.

Fourth, two actions address the priority for low financial costs (SF4A), which results in a lack of priority for circularity (SF4A) (Table 15, action 28 & 31). However, these actions are not focused on the most stated reason for the priority on low financial costs: the difficulty to explain to the taxpayer why they should pay (more) for the circular transition (see chapter 4.3). It is recommended to address this issue through governance action. Possible solutions are: (1) increased collaboration between water authorities and sharing investment costs. This should lower the financial burden on individual taxpayers (mentioned by 1 water authority). (2) Create legitimacy for circularity in order to get support from taxpayers (possibly through administrations, as political representatives of the public).

Fifth, three actions were mentioned regarding the discussion on solution directionality (SF4B) (Table 15, action 17-19). Although these actions try to create a balance between 'low' and 'high' solution directionality, they do not address the major discussion point: “is ‘low’ solution directionality a barrier in this phase of the transition?”. This point of contestation between actors should be openly discussed and result in some form of consensus. Therefore, it is recommended that three specific arguments of this discussion should be settled. First, if waiting to make decisions on solution pathways is worth it if other actors cannot anticipate/invest. Second, if it is more favorable to wait, compared to making choices and reflecting/anticipating afterward. Third, if low solution directionality hampers the ability to finish the mission, as certain assets have a long lifespan (e.g. wastewater treatment plants).

Sixth, the document addressed that water authorities make insufficiently clear/ ambitious requests to contractors and consultancy firms (SF1, SF3, SF5), resulting in discrepancy in philosophies on knowledge diffusion (SF3) (Table 15, action 37, 38). However, it does not address that contractors/ consultancy firms are afraid that they will price themselves out of the market when pro-actively proposing to work/develop something in a circular fashion. Therefore, it is recommended that governance actions address this restraint. This can potentially be done through the usage of an ‘innovation partnership’. This is an innovative form of European tendering in which governmental actors collaborate with technology developers, contractors, and consultancy & engineering firms to develop and implement a circular innovation during a civil engineering project (PIANOo, 2016). This partnership opens the ability for more collaboration between governmental actors and firms (while respecting tender regulation). Additionally, it takes away the ‘fear’ of pricing out of the market, as firms that register in this type of tender do not have to present a turnkey solution during the selection phase. The ‘innovation partnership’ has already been used successfully in the Flood Defenses sub-system and was recommended by interviewees (1 water authority & 1 technology developer) and a field expert (Appendix B, expert 6).

Last, the policy document does address the slow process of lobbying for a relaxation of the regulation (SF7). However, the actions just state that juridical practices and lobbying must continue onward (Table 15, action 34, 35). These actions do not address the slow pace of removing juridical barriers. It is recommended to increase collaboration with regulatory organizations to avoid hinder by regulation at a later stage. This practice is already implemented in the Water Level sub-innovation system, as the Ministry of Infrastructure and Water Management & the Ministry of Agriculture, Nature and Food Quality take part in discussions on the development of circular innovations for biomass (mentioned by 1 Alliance interviewee).

Table 15: Overview of barriers identified in Chapter 4.4 and corresponding governance actions provided by Nanninga & Glas (2021)

| **Barrier** | **No.** | **Transition Pathway** | **Corresponding governance actions by Nanninga & Glas (2021)** |
|---|---|---|---|
| Lack of knowledge and monitoring (SF2 & SF4C), which results in a lack of solution directionality (SF4B) and lack of priority for circularity (SF4A) by water authorities | 1. | Sustainable Commissioning | Water Authorities assess the current situation regarding circularity ($CO_2$ emission and material usage) and monitor their progress |
| | 2. | Sustainable Commissioning | Water authorities that pioneer in specific transition pathways share their knowledge and experience for a shorter learning curve and decrease in costs for other water authorities |
| | 3. | Circular Asset Management | Water authorities assess their assets regarding material inventories and the impact on resources, energy, and environment. The information is stored in a structural and systematic fashion. |
| | 4. | Circular Asset Management | Water authorities assess their material and resource flows and the related emissions |
| | 5. | Circular Asset Management | Water authorities have insights in the materials that are used when building new objects. (i.e. through material sheets requested from contractors and material passports) |
| | 6. | Retrieval of Energy & Resources | Core activities Flood Defenses & Water level can learn from the experiences of the EFGF in Wastewater Treatment |
| | 7. | Retrieval of Energy & Resources | (Research) activities between water management organizations (water authorities, tap water companies & others) should be coupled. |
| | 8. | Retrieval of Energy & Resources | Experiences and knowledge from EFGF employees should be shared in the Quadruple Helix to share successes and learn from past mistakes |
| | 9. | Retrieval of Energy & Resources | EFGF supports in creation a vision what circular wastewater treatment will look like |
| | 10. | Transition Management | Water authorities learn from developments and transitions outside their own sector |
| | 11. | Transition Management | Knowledge and insights sharing within network on concrete and abstract levels. Need for understanding the complexity and necessity of the circular transition. |
| | 12. | Collaboration | Expand monitoring based on joint milestones created within the sector |
| | 13. | Collaboration | Increase collaboration between experts of different sectors. Use their unfamiliarity with the water-sector as an advantage. |
| | 14. | Organizational- & Behavioral Change | Make added value of circularity measurable, regarding both current situation and future opportunities |
| | 15. | Organizational- & Behavioral Change | Create milestones and a clear perspective what should be achieved as circular water authorities |
| | 16. | Organizational- & Behavioral Change | Educate employees of water authorities on circularity |
| Discussion on whether it is 'good' or 'bad' to have low solution directionality (SF4B), resulting in a lack of solution directionality (SF4B) by water authorities | 17. | Circular Asset Management | Assets should be managed driven by circular objectives (circular asset management). Per stage in the lifecycle of an asset, the focus should be on extension of the lifecycle and high-level re-use. |
| | 18. | Collaboration | Evaluate pilots and make decisions regarding which pilots deserve support for upscaling and which ones should be repelled. Quit unnecessary stacking of pilots. |

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|---|---|---|---|
| | 19. | Organizational- & Behavioral Change | Balance between strict solution direction by water authority administration and room for circular initiatives |
| Insufficient time/ interest in the circular transition from employees (SF4A), resulting in a lack of priority for circularity (SF4A) by water authorities | 20. | Transition Management | Through communication, involved stakeholders take away passivity of employees that originates in the abstractness and difficulty of the circular transition. |
| | 21. | Transition Management | By combining circular ambitions with the (strategic) motives of employees, motivation and perseverance is created. |
| | 22. | Organizational- & Behavioral Change | Raise awareness for circularity within the water authorities and learn by doing. |
| | 23. | Organizational- & Behavioral Change | Need for employees in water authorities that can create legitimacy for circularity by supporting, challenging, and stimulating colleagues. |
| | 24. | Organizational- & Behavioral Change | Administration gives employees room to work on circular innovations |
| Lack of creation of legitimacy for circularity in water authorities (SF7), resulting in a lack of priority for circularity (SF4A) by water authorities | 25. | Sustainable Commissioning | Administration gives focus and planning in their administrative assignments, by making the circular mission an obligation, creating milestones, and stimulating Quadruple Helix collaboration |
| | 26. | Organizational- & Behavioral Change | Administration creates legitimacy for circularity within their organization and motivates their employees |
| Focus on core activities, other societal challenges, and financial costs (SF4A), resulting in a lack of priority for circularity (SF4A) by water authorities | 27. | Retrieval of Energy & Resources | Solutions need to be found to re-use nutrients from wastewater in a way that they do not provide any danger regarding (1) heavy metals (2) medicine residues (3) hygiene |
| | 28. | Retrieval of Energy & Resources | Through enthusiasm and focus on value, the introduction of circular solutions should be seen as important in the whole value chain. Focus on a Value Case instead of a Business Case. |
| | 29. | Transition Management | Priority and awareness are necessary to keep the circular transition moving and to make sure it does not fade into the background. |
| | 30. | Organizational- & Behavioral Change | Circularity becomes part of the regular activities within water authorities. It is part of the core activities and not an extra task for a select few employees. |
| | 31. | Organizational- & Behavioral Change | Create insight in the 'true' societal costs and benefits while pricing. Environmental damage and $CO_2$-emission should be considered. |
| Insufficient priority/ support by administration (SF4A, SF7), resulting in a lack of priority for circularity (SF4A) by water authorities | 32. | Sustainable Commissioning | Current financial restrictions cannot result in long-term circular investment delays in administrative assignments |
| | 33. | Retrieval of Energy & Resources | 'Circular water authorities' should get a higher priority on the agenda of administrations |
| Slow process of lobbying for relaxation of regulation (SF7), resulting in innovations keeping stuck in pilot phase (SF5) | 34. | Retrieval of Energy & Resources | Juridical barriers should be removed, as long as this happens in a diligent manner with respect for the reason for the initial juridical protection (i.e. human health) |
| | 35. | Retrieval of Energy & Resources | Dutch Water Authorities follows and influences political developments regarding $CO_2$ pricing and the tax increase for the usage of virgin materials |
| Lack of market formation/ support for upscaling by water authorities (SF5), resulting in innovations keeping stuck in pilot phase (SF5) | 36. | Retrieval of Energy & Resources | Water authorities should guarantee that they can deliver the volume and quality that the market demands. Inter-regional collaborations should be created when the demands cannot be met within a region. |
| Insufficiently clear/ ambitious requests by water authorities to contractors & | 37. | Sustainable Commissioning | Sustainable Commissioning should challenge contractors/firms. Firms get the opportunity to bring added value to the water authorities (provide value-case instead of business case). |

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|---|---|---|---|
| consultancy firms (SF1, SF3 & SF5), resulting in discrepancy in philosophies on knowledge diffusion (SF3) between water authorities and firms | 38. | Organizational- & Behavioral Change | Circular goals of water authorities are clearly described in internal & external inquiries. |
| Lack of priority for circularity by firms (SF4A), resulting in a lack of pro-activity in tenders and circular projects (SF1) by contractors and consultancy firms | 39. | Transition Management | By combining circular ambitions with the (strategic) motives of non-water authority stakeholders, motivation and perseverance is created. Need for understanding of the interests and motivations of stakeholders and how they can be connected to the circular transition in order to participate. |
| | 40. | Collaboration | Ambitions and commitment of actors (e.g., contractors, research institutes & technology developers, etc.) & adjacent sectors should be aligned |
| | 41. | Collaboration | Collaboration and communication between actors are used to create awareness and necessity |
| | 42. | Collaboration | Quadruple Helix collaboration is used to come to agreements and coordination within the value chain |

# 5. Discussion

This section discusses the results from chapter 4 in relation to the theory (chapter 2) and methodology (chapter 3). First, the theoretical implications are discussed, both related to the structural-functional approach of MIS-analysis and the theoretical contributions of this research. Second, the limitations of this research are discussed. Both sections include recommendations for further research.

## 5.1 Theoretical implications

The recently developed structural-functional approach by Wesseling & Meijerhof (2021) was used as a foundation throughout this MIS analysis. Based on the results of this analysis, several insights contribute to the further development of this MIS approach.

First, Wesseling & Meijerhof (2021) adapted System Function 4 by dividing it into SF4A, SF4B, and SF4C. This research encourages this division, as it resulted in valuable insights. Chapter 4.4 (systemic barrier analysis) showed how the three 'directionality' SFs are interrelated yet have specific impacts on other SFs. The division also gave room for more concrete governance action recommendations to address barriers related to SF4A, -4B, and -4C.

However, SF4B resulted in mixed opinions by interviewees regarding SF fulfillment. In general, Wesseling & Meijerhof (2021) distinguish between 'positive' and 'negative' SF fulfillment as an expression of how much the specific function contributes to the achievement of the mission. In most SF's, the 'more' a system function is fulfilled, the better it is for achieving the mission (e.g., the more resources are mobilized (SF6), the better). However, this 'rule of thumb' is not entirely viable for SF4B. As the results show in chapter 4.3 & 4.4, there is much discussion among actors whether 'high' or 'low' solution directionality is better to 'positively' fulfill the SF. Some interviewees mentioned that 'low' solution directionality was a strength, while others experienced it as a weakness. One interviewee that favored a wide variety of solution pathways aptly mentioned: *"So, I think I would score Solution Directionality with a 3.0. But I question whether it should ever score a 5.0"* (1 water authority, translated from Dutch). Results from chapter 4.3 show that nine interviewees find it 'too early' to provide direction regarding solution pathways, indicating that the 'positive' fulfillment of SF4B depends on the phase of the transition. This notion provides an interesting area for future research. It would be valuable for future MIS analyses to understand if 'low' solution directionality should be deemed 'positive' or 'negative', based on the transition phase.

The ambiguity of SF4B fulfillment could potentially be fixed through differentiation between two factors. (1) The first factor indicates whether there is some form of directionality present (or absent). (2) The second factor indicates whether the scope of the directionality is narrow or broad, which can be related to e.g., the transition phase. By making this distinction, the SF can be better understood and easier to score for interviewees.

Second, early drafts of Wesseling & Meijerhof (2021) (i.e., the case study by Meijerhof (2020)) used scores to quantify the fulfillment of SFs. Each interviewee was asked to score the SFs on a scale from 1 (negatively fulfilled) to 5 (positively fulfilled). A similar approach was used during this research. This approach seems to have a few advantages. First, quantifiable scores give a clear-cut overview of the (average) scores given by interviewees. This results in a straightforward form of comparison. Another advantage is that it forces the interviewee to develop an 'overall' judgment per SF, as they tended to fixate on a specific subject within a SF.

However, it is recommended to use these scores with caution. As seen in chapter 4.3, the average given scores per SF fluctuated around 3.0, with a relatively small deviation, which resulted in minimal valuable insights. Furthermore, chapter 4.3 shows that SF2 scored the highest average score regarding

SF fulfillment. While this might seem to indicate that SF2 is not as much of a barrier for mission achievement, chapter 4.4 identified SF2 as one of the primary root causes for insufficient fulfillment of SF4A & SF4B within the Mission Arena.
Therefore, it is recommended that researchers critically review the added value of SF quantification in future MIS analyses. Scores can be used as a helpful tool for creating an overview during the research process, yet researchers should refrain from using it as a method to decide which SFs act as a barrier for mission achievement.

Third, this research shows the difficulty of implementing barriers related to 'expanding the mission' in the Systemic Barrier Analysis. During the System Function Analysis (chapter 4.3), it was mentioned that MIS actors find it difficult to look at the 'larger perspective' of circularity (mentioned in SF2, SF3 & SF4B). The actors focus on achieving '100% circular water authorities' but lack insight into how they can contribute to circularity in other sectors. While this can be seen as a weakness of the MIS, it is not directly a barrier for mission achievement, as 100% circular water authorities are achievable without supporting neighboring sectors. For this reason, the weakness regarding the 'lack of larger perspective' was not taken up in the barrier network (Figure 4, chapter 4.4). Nevertheless, multiple interviewees mentioned this as an apparent issue. This provides an interesting area for theoretical exploration, both in terms of mission delineation and how these types of issues should be incorporated in future MIS analyses.

Fourth, this research contributed to the body of MIS literature by introducing 'sub-innovation systems' as a method of analyzing a MIS. Incorporating this contribution in the structural-functional approach by Wesseling & Meijerhof (2021) resulted in multiple theoretical insights. Overall, the difficulty of implementation and added value of the sub-systems differed per research stage.
Regarding the Problem-Solution diagnosis, the sub-systems added value as Wastewater Treatment, Flood Defenses & Water Level had apparent similarities and differences. There was overlap between the sub-systems in terms of mission-related societal problems (e.g., climate change & resource scarcity). However, in terms of technological solutions, each system had very distinct approaches to tackling the mission.
The Structural Analysis showed that the sub-system had interrelated and unique system components. In terms of Mission Arena, actor types, and institutions, there was much overlap. However, in terms of specific actors, networks, and materiality, there were significant differences identified.
The System Function Analysis gained multiple benefits from the sub-innovation system approach. First, the approach resulted in creating a representative sample that took all three sub-systems into account. Second, statements by interviewees showed that most SF weaknesses were generalizable over the three sub-systems, confirming their interrelatedness. However, for almost every SF, unique weaknesses were also identified per sub-system. This supports the notion that breaking down a MIS in sub-systems is beneficial compared to analyzing three separate mission-oriented innovation systems.
In terms of the Systemic Barrier Analysis, the sub-system approach failed to add value. This research step aims to identify the root causes for weak SF fulfillment and the relations between weaknesses. Although there were sub-system-specific weaknesses identified in the previous stage, the incorporation in the barrier network proved to be challenging. When sub-system-specific weaknesses are connected to other weaknesses in the network, some relations will not represent the overarching MIS. This would increase the complexity of the network even more and hamper its practical use.
Regarding the 'Reflection on (planned) governance actions', the sub-system approach could not contribute to its full potential, primarily due to the case study. There were no policy documents available that included governance actions for specific sub-systems, at this point. This meant that this research could not analyze how specific sub-systems used governance actions to address barriers. However, sub-systems still provided helpful insight for governance action recommendations. Some sub-systems had specific SF strengths, where other sub-systems had a weakness (e.g., monitoring).

These sub-system strengths can provide insights for recommendations to address weaknesses in other sub-systems.
Overall, this contribution resulted in valuable insights in this case study, and it is recommended for future research to assess its viability in other cases. Furthermore, future research could identify the role of sub-systems in the Systemic Barrier Analysis while retaining its practicality.

Finally, this research attempted to bridge MIS- and System Building literature by posing that some actors could act as 'MIS system builders'. This provided an understanding of how certain actors were (1) central in the formulated mission and (2) integral to the interrelation between 'sub-innovation systems'. Currently, the relation between MIS and system building is still understudied. Therefore, this research calls for future research to take this dynamic into account.

## 5.2 Limitations of the research

As stated in the methodology, several measures were taken to uphold the reliability and validity of this research. However, some limitations have been identified.

First, the *internal reliability* was checked through the usage of Krippendorff's Alpha. This resulted in a KALPHA of 0.7389 (Appendix E). This score was deemed acceptable due to the complexity of the coding but fell short of the >0.8 standard for good reliability.

Regarding *external reliability*, this research was limited in its ability to guarantee replicability. Throughout the five stages of the analysis, this research has attempted to rigorously record each step. This creates an opportunity for other researchers to adopt a nearly identical method to analyze this case study. However, as mentioned by Bryman (2016, p. 383): "*it is impossible to 'freeze' a social setting and the circumstances of an initial study*". This is especially true for innovation systems, as they are very dynamic, and system functions change over time (Suurs & Hekkert, 2009; Negro et al., 2007).

In terms of *external validity*, the ability for a MIS case study to be generalized over social settings is limited. Every mission is unique (Janssen et al., 2020; Wittmann et al., 2020), which hampers the ability to generalize statements that are apply from one case study to another (Ständer, 2019). However, as shown in the 'Theoretical implications' section, some generalizable insights were given based on theoretical constructs and how they relate to the case study results (Riege, 2003), e.g., the novel insights on solution directionality fulfillment (SF4B).

There is one relevant limitation in the Structural Analysis. The Mission Arena consists of 21 regional water authorities, the Dutch Water Authorities, and the EFGF. Based on the description of a Mission Arena by Wesseling & Meijerhof (2021), the small representation of actor types limits the Arena in this case study. This research was able to identify that water authorities were not very receptive to solution directionality given by firms which hampered mission achievement (Chapter 4.3, SF4B). However, this research could not identify any other significant relations between negative SF fulfillment and low actor-type representation in the Mission Arena. It is recommended for future research on this case study to analyze potential relations, as this could add value to the broader understanding of the Mission Arena concept.

There were two limitations regarding the representativeness of the MIS actors in the System Function analysis. First, the interview sample did not include a member of a water authority administration. The results in chapters 4.3 & 4.4 show that administrations have an important role regarding problem directionality (SF4A), mobilization of resources (SF6), and creation of legitimacy (SF7). Their perspective was not considered due to time constraints, as their importance was identified after the interview phase. Secondly, during the System Functions analysis, the perspectives of the regional water authorities were merged into one 'actor type'. Multiple interviewees mentioned that there are considerable differences between regional water authorities in their behavior towards the circular transition. Therefore, it is recommended that water authorities reflect on the result mentioned in this study and identify which SF strengths and weaknesses refer to them specifically.

There were two limitations in the 'Reflection on (planned) governance actions'. First, as previously mentioned, only one policy document was available at this point that included governance actions tailored explicitly to the MIS. Two drawbacks of using this document were (1) a one-sided perspective on governance actions and (2) the inability to evaluate sub-innovation system-specific actions. It is recommended that future research on this case study will assess if upcoming (sub-system-specific) documents address the barriers that were identified.
Second, as the mission and subsequent governance actions were recently posed, it is too early to evaluate the impact of these actions. Although the policy evaluation and recommendations provided valuable insights, the assessment of governance action's impact would have an additional benefit (Wesseling & Meijerhof, 2021). It is therefore recommended that when the impact becomes more perceptible, governance actions should be assessed again.

Last, this research was conducted during the COVID-19 pandemic. This led to the inevitable limitation that interviews were conducted via video calls, which is generally seen as less preferable than face-to-face interviewing (Krouwel et al., 2019).

# 6. Conclusion

This section states the results of this conducted research. First, it will briefly discuss the results per sub-question. Second, the main research question will be answered.

## 6.1 Sub-questions

In total, seven sub-questions were answered during the five steps of the structural-functional approach for MIS analysis. This section gives a summary of the answers per sub-question.

1. *How do different societal problems and 'wants' relate to the mission?*

The mission is related to societal problems and 'wants' in two distinct ways. First, the transition towards a circular economy is identified as a method to combat societal problems such as resource scarcity, irreversible environmental damage, and international resource dependencies. For regional water authorities, drought as an effect of climate change is specifically important. Secondly, the circular mission is indirectly related to other sustainability ambitions that must be achieved parallel (e.g., emission, biodiversity, health, and safety). Additionally, each innovation sub-system included specific trade-offs between the circular mission and other societal problems. Retaining the value of materials (e.g., through re-use) resulted in a potential increase in $CO_2$ emission and/or health risks.

2. *What technological- and social solutions are relevant to the mission?*

Numerous solutions were identified as pathways to tackle the mission. All technological solutions specifically targeted a sub-innovation system. Wastewater Treatment contains the most significant number of solutions, related to reducing, re-using, and/or recycling wastewater, effluent, cellulose, and sewage sludge (Table 6). Most solutions for Flood Defenses are related to re-using and recycling soil and dredged material in e.g., building materials (Table 7). Water Level solutions focus on retaining the value of mowed biomass through fertilizers, insulation material, fiber products, etc. (Table 8). Last, one social solution was identified, in which citizens are challenged in a playful manner to perform their part in the transition towards circular water authorities (Table 9).

3. *What actors are involved in:*
    A. *setting up the mission arena?*
    B. *the mission formulation?*
    C. *mobilizing MIS components through governance actions?*
    D. *the reflexive governance of the mission?*

The Mission Arena consists of 23 actors: 21 water authorities, the Dutch Water Authorities, and the EFGF. Water authorities set up the Mission Arena as 'system builders' and mobilize actors in their role as managerial governmental organizations. Dutch Water Authorities formulated the mission, support knowledge diffusion within the Arena, advocate the interests of the MIS in the (inter)national political context, and take the lead in monitoring mission progress. The EFGF is an enterprise created by water authority employees dedicated to increasing the pace of circular innovation development.

4. *What actors, networks, institutions and materiality support the development and diffusion of the mission's solution, including the phase-out of harmful goods and practices?*

First, numerous actors have been identified that contribute to mission success. Some of these contributed explicitly to only 1 or 2 sub-systems. All actors can be categorized into ten actor types: regional water authorities, governmental organizations, research institutes, consultancy & engineering firms, technology developers, contractors, waste disposal & recycling organizations, financial organizations, network organizations, and alliances. Second, networks had a distinct national character and consisted of already established relationships within the sector. Some new networks were specifically established to aid collaboration to develop circular innovations and strategies. Third, the institutional component affected the speed of innovation primarily through regulatory barriers that (1) hampered the circular use of 'waste' and (2) strict regulation on tendering. Fourth, materiality relevant to the circular transition (i.e., artifacts and infrastructure) was highly specific to each sub-innovation system.

5. *What are the weakly fulfilled system functions within the MIS?*

Based on the 23 conducted interviews, the strengths and weaknesses of the nine system functions were identified. This analysis did not result in clear-cut 'positively' or 'negatively' fulfilled system functions, as each one contained multiple strengths and weaknesses. Nevertheless, each system function contained numerous unique weaknesses and could be deemed as 'negatively fulfilled'. Although quantifiable scores can be contested (see Discussion), they largely correspond with the argumentation given by the interviewees. The scores fluctuate on average between 2.32 (SF4C) and 3.39 (SF2). These relatively low scores indicate that none of the system functions were adequately fulfilled. Based on the scores alone, SF4C (2.32), SF4A (2.65), and SF4B (2.68) should be deemed as the most negatively fulfilled SF.

6. *What are the underlying root causes for these weak system functions?*

A densely connected network can be identified based on the weak system functions and root causes mentioned by interviewed actors (Figure 4). Each system function is represented in this network, as all of them had severe weaknesses. A general overview shows that specific weaknesses have a central role in this network. First, the lack of knowledge regarding what a circular economy is and how to assess/ measure it (SF2 & SF4C) can be seen as one of the most critical root causes for the lack of solution directionality (SF4B) and problem directionality (SF4A) for circularity. Second, these two directionality-related SFs (SF4A & SF4B) are the main reasons that make it difficult for water authorities to mobilize financial resources to achieve the mission (SF6). The lack of financial resource mobilization (SF6) is the main 'bridge' between the systemic weaknesses in the MIS Arena and the overall MIS. Weak SF6 fulfillment results in the inability for circular innovations in the pilot phase to scale up (SF5) and hampers knowledge diffusion between water authorities and contractors/ consultancy firms (SF3).

7. *Are the existing governance actions addressing the (root causes of) identified barriers and are complementary governance actions necessary?*

To answer this sub-question, a recent policy document was analyzed that contains 90 governance actions that are planned/taken in order to make the transition towards 100% circular regional water authorities. Forty-two of these governance actions addressed identified weaknesses/ root causes. However, only ten root causes were addressed (Table 15). Several root causes were partly addressed, while some were neglected entirely. Recommendations were given to address these so-called 'blind spots'.

## 6.2 Main research question

To reiterate, the main research question is:

<u>How can innovative solution pathways develop and diffuse more rapidly in order to make Dutch regional water authorities operate completely circular in 2050?</u>

To conclude, by recognizing the MIS structure and embedded barriers, (planned) governance actions can be deemed appropriate for addressing some of these barriers. However, multiple obstructions are partially addressed or completely neglected. Chapter 4.5.2 gives a complete overview of all blind spots and related recommendations for governance actions. By implementing these recommended actions to address blind spots in current/planned policy, innovative solution pathways will be able to develop and diffuse more rapidly in order to achieve 100% circular regional water authorities in 2050.

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# Appendices

## Appendix A: Overview of concept descriptions

This appendix contains an overview of the concepts (and their definitions) discussed in chapter 2 (Theory). Some definitions are stipulative because (1) no definition was found that completely covered the concept or (2) existing definitions were not tailored towards a MIS. This is explicitly mentioned, with sources that were used to create a new definition.

Table 16: Overview of the concepts discussed in Chapter 2 (Theory) and corresponding definitions

| **Concept** | **Definition** | **Source** |
|---|---|---|
| Grand societal challenge | Challenges that are characterized by:<br>• *"The longer term sustainability of a society or country is at stake*<br>• *Mission oriented, looking at solving societal problems and systemic solutions*<br>• *Multi-level, multi-stakeholder participation*<br>• *Focused on alignment and coordination of strategies*<br>• *Linking economic growth to societal benefits*<br>• *Combining research, technology & innovation in a multi-disciplinary way"* | (Daimer et al., 2014, p. 3) |
| Mission | *"an urgent strategic goal that requires transformative systems change directed towards overcoming a wicked societal problem."* | (Hekkert et al., 2020, p. 76) |
| Mission-oriented Innovation Policy (MIP) | *" a directional policy that starts from the perspective of a societal problem, and focuses on the formulation and implementation of a goal-oriented strategy by acknowledging the degree of wickedness of the underlying challenge, and the active role of policy in ensuring coordinated action and legitimacy of both problems and innovative solutions across multiple actors."* | (Wanzenböck et al., 2020, p. 476) |
| Transformative Innovation Policy (TIP) | *" transformative innovation policy can be seen as a shift [...], opening up the policy agenda from primarily economic to broader societal and environmental concerns."* | (Diercks et al., 2019, p. 884) |
| Innovation System (IS) | *"The network of institutions in the public and private sectors whose activities and interactions initiate, import, modify, and diffuse new technologies"* | (Freeman, 1987, p. 1) |
| Technological Innovation System (TIS) | *" a network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure or set of infrastructures and involved in the generation, diffusion, and utilization of technology."* | (Carlsson & Stankiewicz, 1991, p. 111) |
| Mission-oriented Innovation System (MIS) | *"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) |

| | | |
|---|---|---|
| Social innovation | *"social innovations comprise new ways of doing (practices, technologies, material commitments), organizing (rules, decision-making, modes of governance), framing (meaning, visions, imaginaries, discursive commitments) and knowing (cognitive resources, competence, learning, appraisal)"* | (Pel et al., 2020, p. 3) |
| MIS actors | MIS actors consists of those who "*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) |
| MIS arena | *"refers to actors that are engaged in the highly political and often heavily contested process of mission governance"* | (Wesseling & Meijerhof, 2021, p. 3) |
| Mission Governance | *"providing direction to the MIS as well as mobilizing and aligning existing innovation system structures into a semi-coherent ensemble that aims to pursue the mission. This direction is provided by the mission goal and by complementary governance actions."* | (Wesseling & Meijerhof, 2021, p. 7) |
| Governance Actions | *"actions that the mission arena participants have committed to, in support of the mission's pursuit."* | (Wesseling & Meijerhof, 2021, p. 13) |
| System Functions | *"refers to 'what is achieved in the system' in terms of processes that have a more direct and immediate impact on the 'goal' of the system"* | (Bergek et al., 2010, p. 8,9) |
| Entrepreneurial activities | Stipulative definition: *"Experiments with uncertain outcomes (risk) through: i.e. developing new and existing solutions, entering new markets and innovating business models"* | Based on (Wesseling & Meijerhof, 2021), (Hekkert et al., 2007), and (Bergek et al., 2010) |
| Knowledge development | Stipulative definition: *"The development of knowledge through 'learning by doing' and 'learning by searching'. The developed knowledge leads to a better understanding of the societal problem and the solution pathways."* | Based on (Wesseling & Meijerhof, 2021) and (Hekkert et al., 2007) |
| Knowledge diffusion | Stipulative definition: *"The exchange of information in networks containing knowledge regarding relevant societal problems and solution pathways through different media, e.g. reports, conferences, workshops, etc."* | Based on (Wesseling & Meijerhof, 2021) and (Hekkert et al., 2007) |
| Problem Directionality (System Function) | *"The direction provided to stakeholders' societal problem conceptions and the level of priority they give it."* | (Wesseling & Meijerhof, 2021, p. 11) |
| Solution Directionality (System Function) | *"The direction given, both by existing system structures and the mission arena, to the search for new and further development of existing technological and social solutions, as well as the coordination efforts needed to identify, select, and exploit synergetic sets of solutions to the mission."* | (Wesseling & Meijerhof, 2021, p. 11) |

| | | |
|---|---|---|
| Reflexive Governance | *"Reflexive deliberation, monitoring, anticipation, evaluation and impact assessment procedures; these provide the analytical and forward-looking basis for redirecting the system's problem framing and search for solutions based on lessons learned and changing context. Reflexive governance can be seen as second-order directionality, and it can be initiated by the mission arena or by critical outsiders."* | (Wesseling & Meijerhof, 2021, p. 12) |
| Market Formation | Stipulative definition: *"Creation of niche markets or favourable tax regimes to protect new solutions during development and diffusion. Support for innovation scale-up. Phasing out current practices and/or technologies that could negatively influence the mission."* | Based on (Wesseling & Meijerhof, 2021) and (Hekkert et al., 2007) |
| Resource (re)allocation | Stipulative definition: *"Allocation of sufficient (human-, financial- and physical) resources to support all key activities/functions of the innovation system."* | Based on (Wesseling & Meijerhof, 2021), (Hekkert et al., 2007) and (Hekkert et al., 2011) |
| Creation and Withdrawal of legitimacy | Stipulative definition: *"Counteract resistance to change and create legitimacy through (vocal) support by stakeholder groups, the public and other actors. Acceptance and compliance by relevant institutions. This should lead to: (1) prioritization of the underlying problems of the mission, and support for solution pathways. (2) withdrawal of legitimacy for practices harmful to mission success."* | Based on (Wesseling & Meijerhof, 2020), (Hekkert et al., 2007), (Hekkert et al., 2011) and (Bergek et al., 2010) |
| Systemic barriers | *"structural components (actors, networks, institutions, or materiality) that are missing or unable to support the system functions, thus hampering the functioning of the overall system"* | (Wesseling & Meijerhof, 2021, p. 13) |
| System Building | *"the deliberate creation or modification of broader institutional or organizational structures (system resources) in a technological innovation system carried out by innovating actors."* | (Musiolik et al., 2012, p. 1035) |
| System Builder | *"A system builder is an actor that (consciously) seeks to contribute to the innovation system build up and to strengthen the key processes (functions) in an innovation system"* | (Negro et al., 2012, p. 3844) |

# Appendix B: Expert consultation

During this research, multiple field experts were consulted. These conversations were used to understand the context and buildup of the MIS (stage 1&2 of the MIS-analysis) and the (planned) governance actions (stage 5).

These conversations were not analyzed in-depth, as in the case of the 23 interviews. Instead, these consist of shorter, less-structured conversations or e-mails with experts on specific topics. Table 17 consists of a list of all experts that were consulted. A general description is given of their expertise. However, to keep their anonymity, their names and the names of the affiliated organizations are not displayed. All experts, except for expert 1, were employees of Dutch regional water authorities. Additionally, Table 17 also includes the sub-innovation system to which the expert is affiliated.

Table 17: Overview of consulted field experts, their expertise and topics of consultation

| Expert nr. | Sub-Innovation System | Expertise | Topics of consultation | Date of consultation |
|---|---|---|---|---|
| 1 | All 3 | Researcher circular transition water authorities | • Circular innovations<br>• Scientific literature on circular transition in water-sector | Multiple times |
| 2 | All 3 | Project leader & coordinator sustainable commissioning | • Societal problems related to the mission<br>• Circular innovations<br>• Relevant MIS actors<br>• Mission Arena<br>• Relation between water authorities and non-governmental actors | Multiple times |
| 3 | All 3 | Sustainability manager | • Societal problems related to the mission<br>• Circular innovations<br>• Relevant MIS actors<br>• Role of water authority administrations<br>• Mission Arena | Multiple times |
| 4 | All 3 | Communication advisor | • Social solutions for sustainability<br>• Phase-out of harmful practices | 17-2-2021 |
| 5 | Flood Defenses | Technical manager regional flood defenses | • Societal problems related to the mission<br>• Circular innovations in sub-system<br>• Phase-out of harmful technologies & practices | 4-3-2021 |
| 6 | Flood Defenses | Project manager flood defenses | • Societal problems related to the mission<br>• Innovation partnership<br>• Circular innovations in sub-system | 28-1-2021 |
| 7 | Wastewater Treatment | Process expert wastewater treatment installations | • Societal problems related to the mission<br>• Circular innovations in sub-system<br>• Phase-out of harmful technologies & practices | 9-2-2021 |
| 8 | Water Level | Region manager | • Societal problems related to the mission<br>• Circular innovations in sub-system<br>• Phase-out of harmful technologies & practices | 24-2-2021 |
| 9 | Water Level | Region manager | • Societal problems related to the mission<br>• Circular innovations in sub-system<br>• Phase-out of harmful technologies & practices | 24-2-2021 |
| 10 | All 3 | Policy advisor sustainability | • Circular transition management<br>• (Planned) governance actions circular transition<br>• Recent policy documents on circular transition relevant to the MIS | Multiple times |

# Appendix C: Interview Guide (Dutch)

This appendix consists of the interview guide that was used during the interviews. As all interviews were conducted in Dutch, the interview guide was also written in Dutch. For a translation of the interview guide, see Appendix D.

Before conducting the interviews, a few essential steps were taken. First, each interviewee received an e-mail with a brief introduction to the MIS concept and a description of the nine system functions. The descriptions were based on the work by (Elzinga et al., 2020). This work provides clear and concise SF descriptions in Dutch, and multiple authors also contributed to Hekkert et al. (2020), a foundational article for the MIS concept.
Secondly, each interviewee was asked if they would agree to record interview audio. Each interviewee gave his/her informed consent.

(The slightly different names for the system functions are based on an older draft of Wesseling & Meijerhof (2021). These were updated for the Theory & Result sections in this thesis.)

## Vraag 0: Commitment

Waarom/Hoe is uw organisatie gecommitteerd aan het bijdragen aan de doelstelling van de waterschappen om 100% circulair te functioneren voor 2050?

## Vraag 1: Experimenteren door ondernemers

| | | | | | |
|---|---|---|---|---|---|
| 1.1 Op een schaal van 1 tot 5, is er voldoende ondernemerschap (startups, nieuwe verdienmodellen, experimenten met nieuwe technologieën) richting circulaire innovatie in uw sector om de circulaire doelstellingen voor 2050 te behalen?<br><br>(1 voor te weinig ondernemerschap, 5 zeer toereikend ondernemerschap) | 1 | 2 | 3 | 4 | 5 |

| |
|---|
| 1.2 Wat is de achterliggende reden voor uw bovenstaande antwoord?<br>1.3 (bij 3 of lager) Wat is de oorzaak of het achterliggende probleem?<br>1.4 Hoe probeert men dit probleem op te lossen?<br>1.5 (Als er geen oplossing is) Wat zou eventueel een oplossing kunnen zijn?<br>1.6 (bij 4) Waarom is het geen 5? |

## Vraag 2: Kennisontwikkeling

| | | | | | |
|---|---|---|---|---|---|
| 2.1 Op een schaal van 1 tot 5, wordt er voldoende kennis ontwikkeld door de sector rondom circulaire innovatie om de circulaire doelstellingen voor 2050 te behalen?<br>(1 voor te weinig kennisontwikkeling, 5 voor zeer toereikende kennisontwikkeling) | 1 | 2 | 3 | 4 | 5 |

| |
|---|
| 2.2 Wat is de achterliggende reden voor uw bovenstaande antwoord?<br>2.3 (bij 3 of lager) Wat is de oorzaak of het achterliggende probleem?<br>2.4 Hoe probeert men dit probleem op te lossen?<br>2.5 (Als er geen oplossing is) Wat zou eventueel een oplossing kunnen zijn?<br>2.6 (bij 4) Waarom is het geen 5? |

## Vraag 3: Kennis verspreiding

| | | | | | |
|---|---|---|---|---|---|
| 3.1 Op een schaal van 1 tot 5, wordt er voldoende kennis verspreid door de sector rondom circulaire innovatie om de circulaire doelstellingen voor 2050 te behalen?<br>(1 voor te weinig kennisverspreiding, 5 voor zeer toereikende kennisverspreiding) | 1 | 2 | 3 | 4 | 5 |

| |
|---|
| 3.2 Wat is de achterliggende reden voor uw bovenstaande antwoord?<br>3.3 (bij 3 of lager) Wat is de oorzaak of het achterliggende probleem?<br>3.4 Hoe probeert men dit probleem op te lossen?<br>3.5 (Als er geen oplossing is) Wat zou eventueel een oplossing kunnen zijn?<br>3.6 (bij 4) Waarom is het geen 5? |

# Vraag 4: Richting geven aan het zoekproces

## Vraag 4A: Prioritering van circulariteit (officiële term: Probleem directionaliteit)

| | | | | | |
|---|---|---|---|---|---|
| 4A.1 Op een schaal van 1 tot 5, in hoeverre wordt er binnen de sector prioriteit geven aan de circulaire ambitie in relatie tot andere relevante maatschappelijke uitdagingen? (1 voor weinig prioriteit, 5 voor veel prioriteit) | 1 | 2 | 3 | 4 | 5 |

| |
|---|
| 4A.2 Wat is de achterliggende reden voor uw bovenstaande antwoord?<br>4A.3 Zitten er grote verschillen tussen de prioriteit die er gegeven wordt door de verschillende organisaties?<br>4A.4 Heeft u het idee dat de hele sector hetzelfde bedoeld als we het over 'circulair' hebben?<br>4A.5 (bij 3 of lager) Wat is de oorzaak of het achterliggende probleem?<br>4A.6 Hoe probeert men dit probleem op te lossen?<br>4A.7 (Als er geen oplossing is) Wat zou eventueel een oplossing kunnen zijn?<br>4A.8 (bij 4) Waarom is het geen 5? |

## Vraag 4B: Prioriteren van oplossingsrichtingen (officiële term: Oplossings directionaliteit)

| | | | | | |
|---|---|---|---|---|---|
| 4B.1 Op een schaal van 1 tot 5, in hoeverre wordt er binnen de sector richting gegeven aan de oplossingen die benodigd zijn voor het behalen van de circulaire doelstellingen voor 2050? (1 voor onvoldoende richting, 5 voor veel richting) | 1 | 2 | 3 | 4 | 5 |

| |
|---|
| 4B.2 Wat is de achterliggende reden voor uw bovenstaande antwoord?<br>4B.3 Zijn er dominante ontwerpen?<br>4B.4 Verschillende oplossingsrichtingen kunnen onderlinge interacties hebben (complementair, competitie, symbiose, etc.). Wordt er gekeken naar deze onderlinge interacties en worden de potentiele voordelen benut?<br>4B.5 (bij 3 of lager) Wat is de oorzaak of het achterliggende probleem?<br>4B.6 Hoe probeert men dit probleem op te lossen?<br>4B.7 (Als er geen oplossing is) Wat zou eventueel een oplossing kunnen zijn?<br>4B.8 (bij 4) Waarom is het geen 5? |

## Vraag 4C: Reflectie & Aanpassingsvermogen (officiële term: Reflexiviteit)

| | | | | | |
|---|---|---|---|---|---|
| 4C.1 Op een schaal van 1 tot 5, in hoeverre wordt er binnen de sector geëvalueerd op de progressie van de ambitie, en op basis daarvan aanpassingen gemaakt om de circulaire doelstellingen voor 2050 te behalen? (1 voor weinig reflectie & aanpassing, 5 voor veel reflectie & aanpassing) | 1 | 2 | 3 | 4 | 5 |

| |
|---|
| 4C.2 Wat is de achterliggende reden voor uw bovenstaande antwoord? |

| |
|---|
| 4C.3 (bij 3 of lager) Wat is de oorzaak of het achterliggende probleem?<br>4C.4 Hoe probeert men dit probleem op te lossen?<br>4C.5 (Als er geen oplossing is) Wat zou eventueel een oplossing kunnen zijn?<br>4C.6 (bij 4) Waarom is het geen 5? |

## Vraag 5: Markt creatie

| | | | | | |
|---|---|---|---|---|---|
| 5.1 Op een schaal van 1 tot 5, wordt er voldoende werk verzet om circulaire innovaties aantrekkelijk te maken in de markt en de verspreiding te bevorderen om zo de circulaire doelstellingen voor 2050 te behalen?<br>(1 voor onvoldoende markt creatie, 5 voor toereikende markt creatie) | 1 | 2 | 3 | 4 | 5 |

| |
|---|
| 5.2 Wat is de achterliggende reden voor uw bovenstaande antwoord?<br>5.3 (bij 3 of lager) Wat is de oorzaak of het achterliggende probleem?<br>5.4 Hoe probeert men dit probleem op te lossen?<br>5.5 (Als er geen oplossing is) Wat zou eventueel een oplossing kunnen zijn?<br>5.6 (bij 4) Waarom is het geen 5?<br>5.7 In hoeverre is de sector bezig met het uitfaseren en/of destabiliseren van activiteiten en technologieën die schadelijk zijn voor het behalen van de ambitie? |

## Vraag 6: Mobiliseren van middelen

| | | | | | |
|---|---|---|---|---|---|
| 6.1 Op een schaal van 1 tot 5, worden er voldoende middelen (financieel, menselijk & materiaal) door de sector beschikbaar gesteld om circulaire innovaties te ontwikkelen en te verspreiden om de circulaire doelstellingen voor 2050 te behalen?<br>(1 voor onvoldoende mobilisatie van middelen, 5 voor toereikende mobilisatie van middelen) | 1 | 2 | 3 | 4 | 5 |

| |
|---|
| 6.2 Wat is de achterliggende reden voor uw bovenstaande antwoord?<br>6.3 Zitten er grote verschillen tussen hoeveel middelen organisaties mobiliseren in de sector om de doelstelling te behalen?<br>6.4 (bij 3 of lager) Wat is de oorzaak of het achterliggende probleem?<br>6.5 Hoe probeert men dit probleem op te lossen?<br>6.6 (Als er geen oplossing is) Wat zou eventueel een oplossing kunnen zijn?<br>6.7 (bij 4) Waarom is het geen 5? |

## Vraag 7: Tegengaan van weerstand

| | | | | | |
|---|---|---|---|---|---|
| 7.1 Op een schaal van 1 tot 5, in hoeverre probeert de sector de weerstand tegen circulaire innovaties te verzwakken om de circulaire doelstellingen voor 2050 te behalen?<br>(1 voor onvoldoende tegengaan van weerstand, 5 voor toereikend tegengaan van weerstand) | 1 | 2 | 3 | 4 | 5 |

| |
|---|
| 7.2 Wat is de achterliggende reden voor uw bovenstaande antwoord?<br>7.3 (bij 3 of lager) Wat is de oorzaak of het achterliggende probleem?<br>7.4 Hoe probeert men dit probleem op te lossen?<br>7.5 (Als er geen oplossing is) Wat zou eventueel een oplossing kunnen zijn?<br>7.6 (bij 4) Waarom is het geen 5? |

# Appendix D: Interview Guide (English)

This appendix consists of the translation of the Dutch interview guide presented in Appendix C. This appendix is purely for translation purposes, as all interviews were conducted in Dutch.

## Question 0: Commitment

Why/How is your organization committed to contributing to the mission of the water authorities to operate 100% circular in 2050?

## Question 1: Entrepreneurial Activities

| | | | | | |
|---|---|---|---|---|---|
| 1.1 On a scale from 1 to 5, is there enough entrepreneurial activity (start-ups, new business models, experimentation with new technologies) towards circular innovation in your sector to achieve the circular mission by 2050?<br><br>(1 for insufficient entrepreneurial activities, 5 for more than sufficient entrepreneurial activities) | 1 | 2 | 3 | 4 | 5 |

| |
|---|
| 1.2 What is the reason for the score you gave?<br>1.3 (when giving a 3 or lower) What is the reason or underlying problem?<br>1.4 How do MIS actors try to solve this problem?<br>1.5 (If there is no solution) What could be a potential solution in the future?<br>1.6 (when giving a 4) What is the reason for not scoring a 5? |

## Question 2: Knowledge Development

| | | | | | |
|---|---|---|---|---|---|
| 2.1 On a scale from 1 to 5, is there sufficient knowledge development by the sector regarding circular innovation to achieve the circular mission by 2050?<br><br>(1 for insufficient knowledge development, 5 for more than sufficient knowledge development) | 1 | 2 | 3 | 4 | 5 |

| |
|---|
| 2.2 What is the reason for the score you gave?<br>2.3 (when giving a 3 or lower) What is the reason or underlying problem?<br>2.4 How do MIS actors try to solve this problem?<br>2.5 (If there is no solution) What could be a potential solution in the future?<br>2.6 (when giving a 4) What is the reason for not scoring a 5? |

## Question 3: Knowledge Diffusion

| | | | | | |
|---|---|---|---|---|---|
| 3.1 On a scale from 1 to 5, is there sufficient knowledge diffusion by the sector regarding circular innovation to achieve the circular mission by 2050?<br><br>(1 for insufficient knowledge diffusion, 5 for more than sufficient knowledge diffusion) | 1 | 2 | 3 | 4 | 5 |

| |
|---|
| 3.2 What is the reason for the score you gave?<br>3.3 (when giving a 3 or lower) What is the reason or underlying problem?<br>3.4 How do MIS actors try to solve this problem?<br>3.5 (If there is no solution) What could be a potential solution in the future?<br>3.6 (when giving a 4) What is the reason for not scoring a 5? |

# Question 4: Providing Directionality

## Question 4A: Problem Directionality

| | | | | | |
|---|---|---|---|---|---|
| 4A.1 On a scale from 1 to 5, to what extent does the sector give priority to the circular mission compared to other relevant societal challenges?<br><br>(1 for insufficient priority, 5 for more than sufficient priority) | 1 | 2 | 3 | 4 | 5 |

4A.2 What is the reason for the score you gave?
4A.3 Are there large differences in the priority that is given by different organizations?
4A.4 Do you have the idea that the sector means the same when talking about 'circularity'?
4A.5 (when giving a 3 or lower) What is the reason or underlying problem?
4A.6 How do MIS actors try to solve this problem?
4A.7 (If there is no solution) What could be a potential solution in the future?
4A.8 (when giving a 4) What is the reason for not scoring a 5?

## Question 4B: Solution Directionality

| | | | | | |
|---|---|---|---|---|---|
| 4B.1 On a scale from 1 to 5, to what extent does the sector give direction to the solutions that are necessary to achieve the circular mission by 2050?<br><br>(1 for insufficient solution directionality, 5 for more than sufficient solution directionality) | 1 | 2 | 3 | 4 | 5 |

4B.2 What is the reason for the score you gave?
4B.3 Are there any dominant designs?
4B.4 Different solution pathways can have interactions (complementarity, competition, symbiosis, etc.) Is there any attention for these interactions and are potential benefits exploited?
4B.5 (when giving a 3 or lower) What is the reason or underlying problem?
4B.6 How do MIS actors try to solve this problem?
4B.7 (If there is no solution) What could be a potential solution in the future?
4B.8 (when giving a 4) What is the reason for not scoring a 5?

## Question 4C: Reflexivity

| | | | | | |
|---|---|---|---|---|---|
| 4C.1 On a scale from 1 to 5, to what extent does the sector evaluate the progress of the mission and adjust accordingly to achieve the circular mission by 2050?<br><br>(1 for insufficient reflexivity, 5 for more than sufficient reflexivity) | 1 | 2 | 3 | 4 | 5 |

4C.2 What is the reason for the score you gave?
4C.3 (when giving a 3 or lower) What is the reason or underlying problem?
4C.4 How do MIS actors try to solve this problem?
4C.5 (If there is no solution) What could be a potential solution in the future?
4C.6 (when giving a 4) What is the reason for not scoring a 5?

# Question 5: Market Formation

| | | | | | |
|---|---|---|---|---|---|
| 5.1 On a scale from 1 to 5, to what extent is there enough action taken to make circular innovations attractive for potential buyers/ users to support diffusion in order to achieve the circular mission by 2050?<br><br>(1 for insufficient market formation, 5 for more than sufficient market formation) | 1 | 2 | 3 | 4 | 5 |

| |
|---|
| 5.2 What is the reason for the score you gave?<br>5.3 (when giving a 3 or lower) What is the reason or underlying problem?<br>5.4 How do MIS actors try to solve this problem?<br>5.5 (If there is no solution) What could be a potential solution in the future?<br>5.6 (when giving a 4) What is the reason for not scoring a 5?<br>5.7 To what extent does the sector try to phase-out/ destabilize activities and technologies that are harmful to achieving the mission? |

## Question 6: Resource Mobilization

| | | | | | |
|---|---|---|---|---|---|
| 6.1 On a scale from 1 to 5, are there enough resources (financial, human & physical) mobilized by the sector to support the development and diffusion of circular innovation in order to achieve the circular mission by 2050?<br><br>(1 for insufficient resource mobilization, 5 for more than sufficient resource mobilization) | 1 | 2 | 3 | 4 | 5 |

| |
|---|
| 6.2 What is the reason for the score you gave?<br>6.3 Are there large differences between the amount of resources that are mobilized in the sector to achieve the mission?<br>6.4 (when giving a 3 or lower) What is the reason or underlying problem?<br>6.5 How do MIS actors try to solve this problem?<br>6.6 (If there is no solution) What could be a potential solution in the future?<br>6.7 (when giving a 4) What is the reason for not scoring a 5? |

## Question 7: Counteract resistance to change

| | | | | | |
|---|---|---|---|---|---|
| 7.1 On a scale from 1 to 5, to what extent does the sector try to counteract resistance to the development and diffusion of circular innovations in order to achieve the circular mission by 2050?<br><br>(1 for insufficient counteracting resistance to change, 5 for more than sufficient counteracting resistance to change) | 1 | 2 | 3 | 4 | 5 |

| |
|---|
| 7.2 What is the reason for the score you gave?<br>7.3 (when giving a 3 or lower) What is the reason or underlying problem?<br>7.4 How do MIS actors try to solve this problem?<br>7.5 (If there is no solution) What could be a potential solution in the future?<br>7.6 (when giving a 4) What is the reason for not scoring a 5? |

# Appendix E: Krippendorff’s Alpha

This Appendix consists of the data based on which Krippendorff’s Alpha was calculated. Table 18 shows the 30 statements that were extracted from the interviews. These were sent to three reviewers (Obs 2, Obs 3 & Obs 4), who labelled each statement with a system function. The reviewers chose the system function that, according to them, best captured the content of the statement.
The observations of the researcher and the 3 reviewers were put in SPSS Statistics to calculate Krippendorff’s Alpha. This resulted in a KALPHA value of 0.7389 (See the screenshot in Figure 6).

Table 18: Overview of statements (extracted from interview data) and the corresponding SF labels given by reviewers

| No. | Statement | Obs 1 (researcher) | Obs 2 | Obs 3 | Obs 4 |
|---|---|---|---|---|---|
| 1. | Binnen [waterschap X] niet zo'n hele grote prioriteit. Nee, binnen [waterschap X] is een heel erg veel focus op het wegwerken van achterstanden en dat doen ze dan heel projects-gerichte aanpak en dat wil zeggen dat ze niet zich dan kunnen permitteren om zich nog te laten lastigvallen door circulariteit en dat soort dingen. En dat is niet zozeer onwil, maar gewoon, de focus ligt op … [verwijderd i.v.m. anonimiteit] … achterstanden wegwerken en doen wat ze moeten doen van het geld wat er is. | **SF4A** | **SF4A** | **SF4A** | **SF4A** |
| 2. | Hoe zorg je ervoor dat iets wat, Naja. Ik ben zelf een beetje, ik zie bij klimaatverandering, zie ik hetzelfde. Waar ik dan zelf veel mee bezig ben. Ja, er zijn een aantal specialisten die heel goed weten wat al die gevolgen zijn. Maar hoe zorg je er nou voor dat iedereen die straks iets doet zich dat in het achterhoofd heeft? Want dat vraagt echt een heel ander traject dan het intern met dat kleine clubje op poten zetten. | **SF3** | **SF3** | **SF7** | **SF3** |
| 3. | Uhm, ik denk dat er soms te weinig, zeker, dus als je financiële middelen misschien nog tot daaraantoe. Ook al is gewoon bij ingenieursbureaus wel vaak, de kosten zijn gewoon de manuren, dus gewoon de uren die je eraan besteed. De menselijke uren. Maar denk dat daar wel, dat het daar soms wel aan schort hoor, denk ik. Qua Het vrijmaken van uren die niet per se door berekenbaar zijn en dus niet direct leiden tot een positief resultaat op project. Om daar voldoende tijd vrij te maken dat, dat zie ik binnen mijn eigen organisatie. Ee wordt nog best wel bij veel Ingenieursbureaus, adviesbureaus, best wel gestuurd op billable uren. En wat minder op de uren die uiteindelijk in tweede instantie leiden tot opbrengst. | **SF6** | **SF6** | **SF6** | **SF6** |
| 4. | Wel denk ik als ik kijk naar de waterschappen. Die zijn altijd heel vaak, door iedereen gedacht, in iedergeval, dat is mijn beeld, van: "waterschappen zijn conservatief en de markt niet." Maar ik ben, die mening deel ik niet. Toen ik bij [waterschap X] werkte, heb ik gezien dat [waterschap X] wel zeker Het risico durfde te nemen om op om te ondernemen. Terwijl Ik weet dat heel veel markten op hetzelfde onderwerp dat niet doen. En die hebben ook hun aandeelhouders vaak staan. Die mogen ook geen risicovolle zakendoen. | **SF1** | **SF1** | **SF1** | **SF1** |
| 5. | Ik hoop dat dat ook op een goede manier wordt meegenomen in die circulaire aanpak die de Unie nu aan het ontwikkelen is, samen met de waterschappen. Maar ik vind het wel goed om wel, nou ja, ik weet niet of je op jaarbasis op een wat langere termijn moet zijn, maar het is wel goed om te kijken van: "Okay, deze focus brengen we aan". Maar dan zou ik ook een stapje verder willen gaan. En dan zeggen van: "Okay en welke waterschappen gaan dan waarvoor de handschoen opnemen?" Zodat, dat hangt een beetje samen met, weet je wel dat je niet wil dat iedereen hetzelfde wiel aan het uitvinden is, keer op keer. Is dat je zou kunnen zeggen van: "oké. Dit jaar gaan er een x aantal waterschappen aan de slag. En een doet dit, de ander doet dat", weet je wel, dat het een soort van carrousel wordt of een wedstrijd waarbij je steeds een stokje gaat doorgeven aan elkaar. | **SF4B** | **SF4B** | **SF4B** | **SF4B** |

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| 6. | We hebben natuurlijk de energie en grondstoffen fabriek, …[verwijderd i.v.m. anonimiteit].... Dat is een platform waar we zoveel mogelijk delen. Wat ik wel zie is dat daar ook wel 'the usual suspects' acteren. Heel sterk dat een aantal waterschappen komt naar voren, maar als ik kijk naar 21 waterschappen. Daar zijn een paar die zie ik daar gewoon niet of nauwelijks. | **SF3** | **SF3** | **SF3** | **SF3** |
| 7. | Ik weet niet wat er aan de hand is bij de ministeries, maar dit is blijkbaar toch een heel lastig punt. Om om met name die die als het dan gaat om de verwaarding van reststromen bijvoorbeeld de afvalstatus van, van reststromen uit afvalwater, om die afvalstatus d'r af te krijgen. Maar ook bijvoorbeeld om om wetgeving te versoepelen zodat het gewoon makkelijker dingen her kunnen gebruiken. | **SF7** | **SF7** | **SF5** | **SF7** |
| 8. | …je ontkomt er niet aan om op meerdere paarden te gaan wedden. En soms merk je wel van dat mensen zeggen van: "ja maar we doen het daar ook!" Dan is mijn antwoord van: "je mag blij zijn dat je straks kan kiezen. Want het zou een luxepositie zijn." Nou, bij cellulose speelt dat bijvoorbeeld, maar ook bij nieuwe technologieën voor het verwerken van zuiveringsslib zie je het ook wel. En natuurlijk, wij zijn natuurlijk ook met een technologie bezig op die vanuit de EFGF verder te brengen. En uiteindelijk, tuurlijk vind ik het fijn dat dat straks de technologie waar wij mee bezig zijn, dat die het bijvoorbeeld gaat worden. Maar ik zou ook heel erg nog steeds heel erg blij zijn als de andere technologie wordt, waarmee ook duurzaamheid voordelen behaald worden. Het is niet zo makkelijk om op die manier in te zitten en d'r naar te kijken. | **SF4B** | **SF4B** | **SF5** | **SF4B** |
| 9. | Het einde afval verhaal [einde afval status, een wet die ervoor zorgt dat materialen bestemt als 'afval' niet hergebruikt mogen worden], we hebben gepusht, geduwde, … [verwijderd i.v.m. anonimiteit] …, zelfs bij een eurocommissaris. Je ziet gewoon geen beweging. Blijf je nadenken. We stoppen A. niet met pushen. Maar we gaan ook keihard nadenken over andere middelen.  Maar wel altijd altijd in het positieve blijven denken. En ook naar het ministerie toe ook. We willen uiteindelijk, willen we allemaal hetzelfde. Ja, de mensen het ministerie willen ook heel graag. Maar goed, ze moeten wel het één en ander moet wel voor ze vrijgemaakt worden om ook daadwerkelijk de boel voor elkaar te krijgen. Ja, nee, dus het is niet makkelijk. Dat is politiek dingetje ook denk ik. Ja, we gaan kijken wat de nieuwe regering gaat worden, En wat zij dan van deze zaak gaan vinden? | **SF7** | **SF7** | **SF7** | **SF7** |
| 10. | Ik zou zeggen van niet, want er, waterschappen zitten heel erg nog in de modus van, om risico's, zeg maar buiten de deur te zetten. Dus, die moet dan bij, zeg maar bij derde partijen liggen. En ik denk als je dit wil gaan doen, dan zul je de risico's moeten gaan delen met elkaar. En traditioneel gezien is dat natuurlijk lastig voor een overheid, om om risico, om risicovol te gaan ondernemen eigenlijk dan he. Zo moet je toch formuleren. Volgens mij kun je alleen maar ondernemen door risico's te nemen. | **SF1** | **SF5** | **SF1** | **SF1** |
| 11. | Misschien is dat een goeie afsluiter, de vraag is: "wil je echt circulaire economie, moet het wel vanuit een land als Nederland komen?" Want hebben wij wel de juiste prikkel, om dan weer heeft analogie met de werknemer bij een waterschap, te trekken. Hebben wij de juiste prikkel om circulair te zijn? Of is het gewoon iets, een modewoord? En denken we: "Goh, daar kunnen we lekker geld aan verdienen aan het idee? Of hebben we het echt? Hebben, hebben we het echt nodig? En ik denk dat euh. Ook ikzelf niet die urgentie voldoende voel. | **SF4A** | **SF7** | **SF4A** | **SF4A** |
| 12. | Ja, maar d'r ontbreekt dus een een systeem een monitoringsysteem, omdat om die data per project op te halen, om dat te kunnen beschouwen op systeemniveau. We zijn wel aan het micro managen binnen projecten, maar ik mis nog een systeem wat er overheen ligt. | **SF4C** | **SF4C** | **SF4C** | **SF4C** |
| 13. | Dus uiteindelijk, een beetje ingewikkeld verhaal, maar waar het uiteindelijk op neerkomt, ter indicatie: we hebben rondom circulair, | **SF2** | **SF2** | **SF2** | **SF2** |

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| | nou: we weten nog niet precies wat circulair inkopen, wanneer je het dan goed doet. Dus wat is eigenlijk 'circulair inkoop' precies? En dan hebben we ook nog eens een keer, dus daar moeten we ook iets mee doen. Dan hebben we de monitor, die is daaraan gekoppeld, van: "hoe monitor je nou wat circulair, wanneer je je secundaire doelen gaat halen?" Dan heb je thema's als materialen paspoorten, moet nog heel veel op ontwikkeld worden en ontdekt worden. Je hebt thema's als marktplaats, waar je eigenlijk mee aan de gang wil gaan. Je wil inzichten hebben in grondstoffen, materialenstromen waar vraagstukken over zijn. Instrumenten zoals DuboCalc of de RMD. Ik vind het nog best wel een breed palet. En dan heb ik het nog niet over veranderkundige vragen van: "hoe doe je dan, wat is nou eigenlijk transitie management? En hoe krijgt die organisatie in verandering? Hoe neem je iedereen mee?" Ik vind het best een behoorlijk pakket aan inhoudelijke vraagstukken. | | | | |
| 14. | Euh, ja, de ligt eraan waar je kijkt he, dus bij bedrijven is natuurlijk ondernemerschap, bij de waterschappen zelf is ondernemerschap. Maar als nu op de huidige tour doorgaan, redden we sowieso volledig circulariteit niet. Het is ook bijna niet te redden trouwens, maar daar... Maar het is anderzijds ook weer niet heel, heel dramatisch. Waterschappen doen heel veel activiteiten op ook circulariteit. Het zit ergens in het midden dan, misschien wel, weet ik veel, een 3. | **SF1** | **SF1** | **SF1** | **SF1** |
| 15. | Een weerstand, zeker als je het over circulair denken hebt, is het de publieke perceptie van: "ga ik een pizza doos maken van gebruikt wc-papier?" bij wijze van spreken. Soms kunnen we aan aan onze kant he, vanuit de Waterschappen zeggen: "Ja, dat gaan mensen niet doen! Dat risico willen we niet nemen. Wij willen zo niet te boek staan van: "die waterschappen zijn wc-papier aan het hergebruiken."" Maar anderzijds, wij weten ook allemaal niet wat in de, hoe nu allerlei producten circulair worden gemaakt. En als je de Keuringsdienst van Waarde of Teun van der Keuken afleveringen af en toe ziet, denk je: "Oh, gaat dat zo?!". | **SF7** | **SF7** | **SF7** | **SF7** |
| 16. | Het is wel belemmerend. Het is een grotere uitdaging om met al die thema's tegelijkertijd met je project rekening rekening te houden. Het is het wordt wel je werk wordt er complexer door. Maar ik heb niet het idee dat het um. Het is niet zo dat men circulariteit niet belangrijk vindt, alleen stikstof en klimaat is nu belangrijker. Het doet meer pijn aan onze economie. | **SF4A** | **SF4A** | **SF4A** | **SF4A** |
| 17. | Uiteindelijk gaat het wel een stuk....ja, nee als ik zo heel scherp nadenk, denk ik wel dat hem daarin zit. Je zal voor jezelf, voor je eigen waterschap werkwijzen moeten ontwikkelen van: "hoe gaan wij om binnen de circulaire economie hoe wij ons werk doen en principes hanteren." | **SF2** | **SF4B** | **SF2** | **SF2** |
| 18. | Soms, wat wel een dingetje is... IP [intellectual property] he. Zeker aan de kant van bedrijven als je iets leuks ontwikkeld hebt van: "Tot hoeverre ben je bereid om kennis te delen?" Dat zijn wel dingetjes. Maar voor de rest, alles wat er is, wordt allemaal wel wel wel goed gedeeld ja. | **SF3** | **SF3** | **SF3** | **SF3** |
| 19. | Wat doe je dan weer tot residu? Uit het residu heb je tot iets gehaald, maar bijvoorbeeld de zware metalen blijven wel achter in het residu. En het residu wordt dan steeds meer op geconcentreerd. Dus wat? Wat doe je dan daar weer mee? Dan kun je die kun je dan weer zware metalen uit terugwinnen? Of iets dergelijks? Ja dan hou je weer wat over, je houdt altijd weer iets over, iets is nieuws. En dan moet je daar weer een oplossing voor zoeken. Ja, daar lopen wij nu wel ook tegenaan in zo'n fosfaat traject. | **SF2** | **SF4B** | **SF4B** | **SF2** |
| 20. | Je kunt als overheid of als waterschap dus ook niet oneindig investeren en zeggen van: nou ja, wij gooien gewoon de Waterschapslasten omhoog, want dat bepalen we zelf. En dan gaan we heel veel investeren in innovatie en educatie. Ja, dat kan natuurlijk ook niet. Dat snap ik ook wel en dat snapt waarschijnlijk bijna iedereen, dus daar moet gewoon een balans zijn. Maar ik denk | **SF6** | **SF6** | **SF6** | **SF6** |

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| | wel dat het belangrijk is dat je als waterschap ook investeert in de innovatie en in de ambitie om circulair te worden en je eigen mensen investeren in je eigen systemen, maar ook in de samenwerking en als waterschap ben je daarbij afhankelijk van andere. Maar dat heb je nodig om om circulair te worden dus. | | | | |
| 21. | Ik denk: "Ja, het is wel goed, maar of het echt, naja, hoeveel procent het dan bijdraagt." Nouja, dat zou je dus ook met zo'n klimaat monitor van: "hoe belangrijk is dat baggeren dan op je hele handelen als waterschap?" Dat durf ik zo niet te zeggen. Dat weet ik niet. | **SF4C** | **SF4C** | **SF4C** | **SF4C** |
| 22. | Ook dat gaat dus eigenlijk best wel goed, als je je verdiept in het onderwerp en je en en je krijgt, je krijgt de uitnodigingen door van conferenties en webinars en je weet de websites te vinden, dan gaat het met de kennis verspreiding ook heel erg goed. Maar dat is eigenlijk voor de mensen die zich met circulaire economie bezighouden. Wat ik merk met de mensen die hiermee uiteindelijk binnen de organisatie mee aan de slag moeten? Dat het nog niet, dat, dat het te ingewikkeld is nog. Dus die mensen melden zich niet aan voor die conferenties of webinars of wordt het veel te technisch, of het is toch te ver van hun bed af. Dus, en de rapporten en de informatie die er nu is, dat is nog, dat is nog te theoretisch en te ingewikkeld. Het moet meer toepassing gericht, wat ik bijvoorbeeld zei van CB23. Die probeert dan voor de bouw handreikingen te ontwikkelen. Maar dat zijn dikke pillen waar je moeilijk doorheen kan komen en moeilijk de essentie uit kan halen. | **SF3** | **SF3** | **SF3** | **SF3** |
| 23. | Er zijn verschillende voorbeelden te geven, waarbij nu nog niet eens duidelijk is wat de huidige situatie precies is. Hoe dat eruitziet? Als voorbeeld hebben … [weggehaald i.v.m. anonimiteit] … dat Circulair Water 2050 gekeken naar grondstoffen die gebruikt worden en die mogelijk gewonnen kunnen worden. En per individueel waterschap of zelfs nog een lager niveau, detail kleiner niveau, is die informatie d'r heel vaak niet of niet heel duidelijk? En als je dat niet duidelijk hebt, is het heel moeilijk om te acteren en te bedenken hoe je circulair kunt worden. Dat is één van de punten he. Dus ook het kunnen meten van de CO2 footprint. Het is best wel ingewikkeld, maar als je dat niet doet, dan zit je eigenlijk in het luchtledige stappen te maken, zonder dat je goed kunt monitoren of die stap dan ook bijdraagt aan een lagere CO2 footprint, bijvoorbeeld. Ik denk dat daar nog zeker wel wat meer aandacht voor mag zijn om goed te evalueren en te monitoren wat we nu hebben. En dan helpt uiteindelijk ook denk ik bij het zetten van de doelen om te verbeteren. | **SF4C** | **SF4C** | **SF4C** | **SF4C** |
| 24. | Alleen het mag niet meer gaan kosten. […] En zolang die gedachtegang erin blijft, dan zal je zien dat het de circulaire economie of de duurzame economie, gestaag groeit, maar niet met de snelheid waarmee het zou kunnen groeien. | **SF6** | **SF6** | **SF6** | **SF6** |
| 25. | En ik ben inderdaad wel iemand die zegt van: "Naja, laat eerst duizend bloemen bloeien." En een vervolgens is het nog steeds de vraag of daar of daar enkele oplossing richtingen uit voort moeten komen. Ik denk dat. Het juist past bij circulariteit, dat is dat je bijvoorbeeld gaat naar lokale oplossingen En ook diversiteit. | **SF4B** | **SF4B** | **SF4B** | **SF4B** |
| 26. | En ik vind [waterschap X] wel een interessant voorbeeld met [dijkversterkings project]. Allemaal heel cool. Maar uiteindelijk de innovaties die er inkomen moeten allemaal minstens TRL 6 zijn. […] Daar word ik dan als uhm, daar word ik niet enthousiast van. En nogmaals, ik denk dat het heel belangrijk is dat ook er een podium is voor de innovatie van TRL 6 en hoger. Uhm, maar wat gaan we doen met de ideeën die op een veel lager TRL-niveau liggen? | **SF5** | **SF5** | **SF4B** | **SF5** |
| 27. | Voldoende weet ik niet, maar in ieder geval niet op de juiste manier. Want wet- en regelgeving wordt niet aangepast, wordt geen kennis gehaald. Er wordt in de ivoren toren wordt wordt bedacht en gaat ontiegelijk stroperig. Uhm. D'r is heel veel sociale weerstand tegen | **SF7** | **SF7** | **SF5** | **SF7** |

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| | circulaire toepassingen of tegen hergebruik van materialen. Ik weet niet of je "de Vuilnisman" gezien hebt. | | | | |
| 28. | Ik heb bij de Marker Wadden, heb ik in het verleden meegedaan, en daar was een, In de aanbesteding ging het over de aanleg van de Marker Wadden, maar er was ook een proefvak voor dun slib, en daar hadden ze gewoon een vast bedrag voor gerekend en degene die de klus won, kreeg gewoon een bedrag om in dat vak zijn eigen innovatie door te ontwikkelen. Punt. En dat was het. En iedereen kreeg hetzelfde bedrag en dan kon je zelf bedenken wat je daar ging doen. Moet je wel een beetje omschrijven. Zo zijn er wel allerlei manieren om toch die ruimte te creëren. | **SF5** | **SF5** | **SF6** | **SF5** |
| 29. | Want hoe nieuwer het is, of hoe innovatiever het is, hoe meer risico je loopt. Euh, dus ja, dan haken waterschappen ook nog snel af. Want dan hebben ze zoiets van: "nou, laten we eerst maar eens door ontwikkelen, laten door ontwikkelen door anderen. En als dan blijkt dat het inderdaad werkt dan willen we het wel gaan omarmen". Ja, en dan ben je eigenlijk al te laat, ook al is dat misschien nog wel redelijk nieuw. | **SF5** | **SF5** | **SF1** | **SF7** |
| 30. | Nee, ik denk dat we dat onvoldoende doen. In ieder geval niet expliciet. Maar ik heb wel altijd het idee. Dat is ook best lastig. En wat, ook in je eigen psyche, van: "heb ik het dan altijd verkeerd gedaan?". En je voelt je een beetje aangevallen. Dus ik heb ook meer vertrouwen in dat dat op een natuurlijke manier ontstaat. Dus op het moment dat je helemaal gewend bent op een bepaalde manier, je zaak, je werk aan te vliegen. Als je dan dus ook automatisch het andere niet meer doet en dat dat soort uitfaseert vanzelf. Een soort natuurlijk traject of misschien komt er echt wel een moment dat je zegt: "Hey, we hebben nu deze twee naast elkaar liggen, deze twee werkwijzen. Waarom doen we dat oude eigenlijk nog, want dat nieuwe, dat werkt eigenlijk prima?". Dus dat we ernaartoe groeien. | **SF5** | **SF1** | **SF6** | **SF4C** |

```
kalpha judges = Obs1 Obs2 Obs3 Obs4/level = 1/detail = 0/boot = 10000.
```

## Matrix

```
[DataSet1] \\Client\H$\Desktop\SPSS Krippendorff.sav

Run MATRIX procedure:

Krippendorff's Alpha Reliability Estimate


              Alpha   LL95%CI   UL95%CI     Units   Observrs     Pairs
Nominal       ,7389     ,6705     ,8073   30,0000     4,0000  180,0000

Probability (q) of failure to achieve an alpha of at least alphamin:
   alphamin          q
      ,9000     1,0000
      ,8000      ,9578
      ,7000      ,1289
      ,6700      ,0216
      ,6000      ,0002
      ,5000      ,0000

Number of bootstrap samples:
  10000

Judges used in these computations:
 Obs1      Obs2      Obs3      Obs4

Examine output for SPSS errors and do not interpret if any are found

------ END MATRIX -----
```

Figure 6: Screenshot of ‘Krippendorff’s Alpha Reliability Estimate’ calculated in SPSS Statistics

# Appendix F: System Function scores per Sub-Innovation System (radar chart)

Figure 7 displays the average scores that were given for each system function per Sub-Innovation System. As the figure indicates, the differences are almost negligible. Two reasons explain this phenomenon. First, the average scores (red dotted line) showed that most interviewees gave somewhat similar scores (between 2.32 (SF4C) and 3.39 (SF2)). This results in a slight fluctuation between sub-innovation systems. Second, multiple actors are part of 2 or 3 sub-innovation systems. Naturally, this results in some form of convergence between scores, as the sample of each sub-system consists of multiple similar actors.

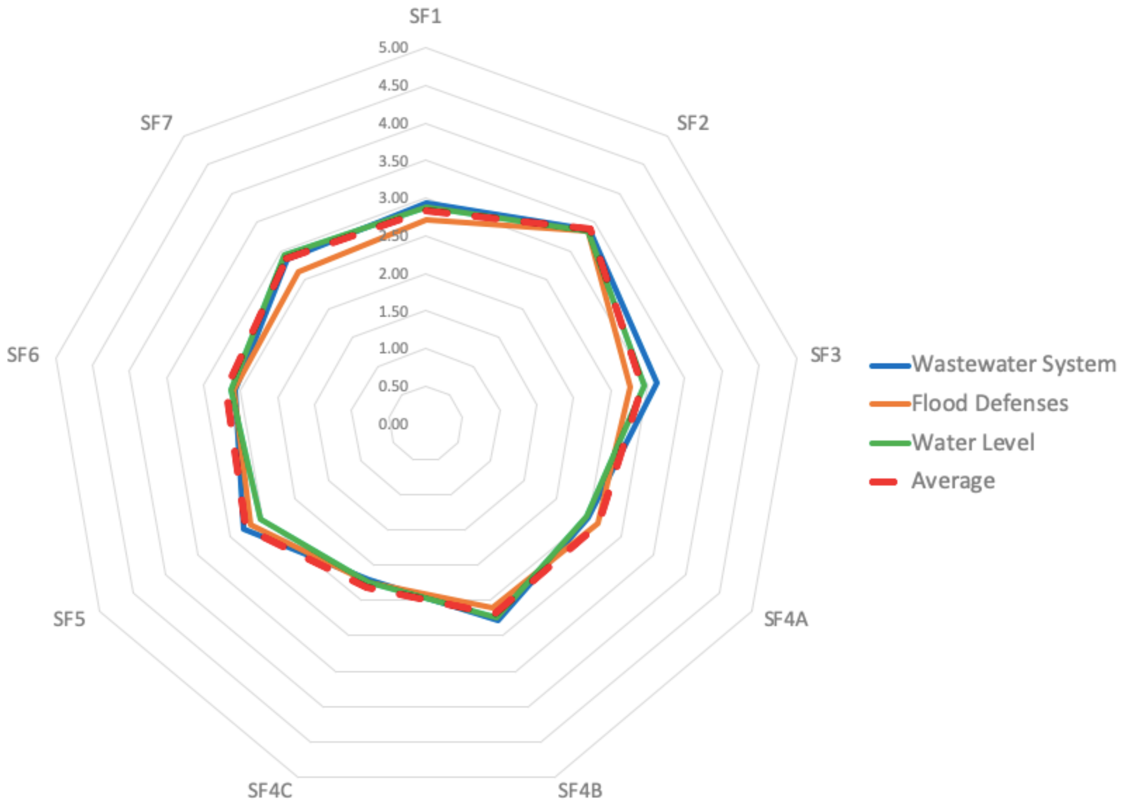


Figure 7: Average scores given by the (actors in the) sub-innovation systems on the fulfillment of 9 system functions (visualized in a radar chart)