



Master's Thesis - Master Innovation Sciences

**MANAGING THE TWIN TRANSITION: THE ROLE OF
RESEARCH AND TECHNOLOGY ORGANIZATIONS IN
CONVERGING THE DIGITAL AND SUSTAINABILITY
TRANSITION**

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Author:

Anne Veldhuis, BSc

Student number: 6277969

Contact: a.y.veldhuis@students.uu.nl

Internship:

Organisation: TNO

Location: The Hague

Supervisor: Dr. A.C. van den Berg & Dr. A. Geurts

Supervision Utrecht University:

Dr. I. Susha

Contact: i.susha@uu.nl

Second reader Utrecht University:

Dr. L. Piscicelli

Master's Thesis – Master Innovation Sciences GEO4-2239X

Faculty of Geosciences, Utrecht University

ABSTRACT

INTRODUCTION

Both the green and digital transitions are of great significance in the society and economy of today. Linking them in the twin transition is critical and has great potential; however, a centralised governing body is missing. Therefore, implementing effective governance mechanisms is imperative to manage the twin transition appropriately. Consequently, the transition management (TM) approach is used. Following the TM approach, actors can significantly guide the twin transition, focusing on one significant actor. Namely, the intermediary actors and mainly research and technology organisations (RTOs), as RTOs are identified as a significant element of a country's innovation system. RTOs possess the potential to contribute to the sustainability transition and hence the twin transition. Therefore, this study aims to explore the contribution of RTOs in the governance of the twin transition.

THEORY

The transition management (TM) approach aims to deepen our understanding of social system transformation and actively promote and facilitate them. The TM framework provides a helpful distinction between four different governance activities. These are strategic, tactical, operational, and reflexive. Specific practices, known as governance tools, have been created for each activity. These are the transition arena, agenda, experiments, and monitoring.

METHODS

A single qualitative case study comprising a Dutch RTO known as the Netherlands Organisation for Applied Scientific Research, TNO, was selected for this study. Semi-structured interviews and the organisation and participation of a twin transition workshop were part of the primary data collected. Several TNO-based documents were identified as secondary data that complemented the primary data throughout the study. The collected data was consequently analysed using an abductive coding approach.

RESULTS

TNO is an example of a case in which the interconnection between digitalization and sustainability is increasingly recognized, whereas sustainability remains the primary focus. Furthermore, it was found that TNO performed several distinct roles in contributing to the governance of the twin transition. These roles are initiating, connecting, boosting, arranging, providing knowledge, guiding, contributing, observing, establishing, facilitating, proactive, motivating, gap analysis, clarifying, and monitoring.

CONCLUSION AND DISCUSSION

The notable gap in existing literature in which little attention has been paid to the role of RTOs in the twin transition is filled by the roles mentioned above. RTOs contribute to the governance of the twin transition by engaging in governance activities through performing these roles. Additionally, this study provides a guideline which further describes actionable steps to enhance RTOs' contribution to the twin transition.

EXECUTIVE SUMMARY

This research was conducted at a Dutch RTO known as the Netherlands Organisation for Applied Scientific Research (TNO) as the researcher performed a six-month internship at the corresponding organisation. TNO pursues the twin transition by putting forward digital and sustainable issues in its mission, however, it is unclear what their contributing role is to the twin transition and how TNO can prioritize this. Through answering the following research question TNO becomes aware of the prioritizing of the twin transition within the organization and its contributing role to the twin transition: *“How can Research and Technology Organizations (RTOs) contribute to the governance of the twin transition?”*.

In this research two units within TNO are investigated, these are the ICT, Strategy & Policy unit, and the Mobility & Built Environment unit. Within these two units, the interconnection between digitalization and sustainability is being recognized, as many interviewees indicate that the two topics are increasingly aligning. However, despite this recognition, sustainability remains the primary focus. Whereas digitalization is often seen as an enabler to achieve sustainability goals. This is not the case for the ICT department as their primary emphasis is directed exclusively towards digitalization, with minimal consideration for sustainability aspects. Furthermore, within TNO several challenges are associated with the convergence of green and digital transitions. These challenges are that the magnitude of the digitalization aspect is often underestimated, that major digitalization initiatives are expected to require considerable effort, the fact that digitalization in its way gives rise to new possibilities that consume substantial quantities of energy, and another common issue is the lack of effective communication and mutual understanding between the ICT department and other departments with the two units.

Furthermore, several roles are identified that show the contributing role of TNO in the twin transition. By performing these roles TNO plays an influential role in the governance of the twin transition. The roles that were identified occur within the four theoretical constructs for the transition management framework used in this research. Namely, the transition arena, transition agenda, transition experiments, and transition monitoring and evaluation. Within the context of the transition arena, several roles are identified namely: the initiating, connecting, boosting, arranging, providing knowledge, presenting, and guidance roles. In the context of the transition agenda, the following roles were recognized: facilitating, proactive, motivating, gap analysis, clarifying, initiating, and providing knowledge roles. In the domain of the transition experiments, the following roles were recognized: the contributing, observing, interconnecting, and establishing roles. Finally, in the transition monitoring and evaluation context, one role is identified which is the monitoring role.

To augment TNO's role in governing the twin transition, a comprehensive guideline was created based on the findings. This guideline outlines various action steps for each theoretical construct, aiming to enhance their contribution. Additionally, this guideline could potentially function as a method to enhance the interconnectedness between the digital and green transition within the organization. The guideline provides TNO with supplementary assistance in comprehending its contributory role within the twin transition but especially provides strategies for prioritizing the convergence between the green and digital transition.

By providing insights into the interconnection between digitalization and sustainability within TNO, delineating the diverse roles undertaken by TNO in the twin transition context, and presenting a guideline that could potentially aid TNO in comprehending and increasing its contributory role to the twin transition, this research addresses the questions of the corresponding organization, namely TNO.

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1. INTRODUCTION

Sustainability and digitalization are two of the main trends shaping the society of today and the future (Del Río Castro et al., 2021; Lenz, 2021; Lichtenthaler, 2021). Sustainability has gained much attention throughout the years as the negative influences on the climate continue to rise (Fouquet & Hippe, 2022). Because of the depletion of fossil fuels, the extinction of species, and the dangers presented by climate change, which is accelerating at an alarming rate, it is imperative that societies shift in a more sustainable direction (Lenz, 2021). Sustainability transitions provide a solution as they change unsustainable modes of production into sustainable ones by adopting eco-friendly behaviours that account for environmental expenses (Markard et al., 2012). Additionally, sustainability transitions address biodiversity loss and its numerous ecological services, which are essential for resilient communities and healthy lifestyles (Mace et al., 2018; Rockström et al., 2009). The United Nations General Assembly's adoption of the 17 Sustainable Development Goals in 2015 shows how sustainability has become a recurring subject for political action worldwide (Lenz, 2021; UNITED NATIONS, n.d.).

Alongside the sustainability transition, the unrelenting diffusion of digital technologies and processes resulted in a digital transition (Bednorz & Sadauskaitė, 2022; Eurochambers, 2022). The digital transition originated through the emerging digital technologies that have altered and continue to alter how people and business conduct everyday commercial and personal activities (Andersen et al., 2021). It entails updating more recent technology, automating specific human procedures, and reducing turnaround times by integrating more systems (Rosário & Dias, 2022). The digital transition is one of the most important trends shaping the future of societies and economies (Muench et al., 2022; Parviainen et al., 2017). The prospective benefits of the digital transition are considered high because it can provide long-lasting solutions to many social issues related to climate change that appear intractable (Dwivedi et al., 2022; Lange et al., 2023). Digitalization is even considered one of the most promising transformations for sustainability as it has the potential to make the world around us more intelligent and efficient (Del Río Castro et al., 2021; Fouquet & Hippe, 2022; Parviainen et al., 2017). Digital technologies may significantly improve resilience to climate change and natural disasters, reduce emissions, and make it easier for people to take the required actions to achieve net zero emissions (Del Río Castro et al., 2021). Aside from providing solutions to lessen the effects of climate change, digital technology and data also provide other benefits. In addition, they keep track of these effects and adjust accordingly (DIGITALEUROPE, 2023).

As both the green and the digital transition are of great significance in the society and economy of today, it is critical to link these two transitions to identify how these transitions will interact and where the potential source of tension may exist (Lenz, 2021). The twin transition, which combines the digital and green transitions, can accelerate critical change and get society closer to the required level of transformation (Blüm, 2022; Muench et al., 2022; Somers, 2022). Rather than treating sustainability and digitalization in isolation, the twin transition strategy combines the critical functions to unlock significant benefits in terms of efficiency and productivity (Blüm, 2022). It is envisioned that the twin transition will facilitate sustainable digital transformation and strengthen sustainability with technology (*The Twin transition: A New Digital and Sustainability Framework for the Public Sector*, 2021). However, a uniform approach or centralized governing body for overseeing the twin transition globally is absent as the management and governance of the twin transition exhibit diversity across countries, regions, and sectors (Komninos, 2022; Mäkitie et al., 2023; Muench et al., 2022). Given the potential of the twin transition to expedite crucial changes and drive societal transformation, it is imperative to implement effective management and governance mechanisms. Therefore, the twin transition should be managed and

governed appropriately using a governance paradigm focused on guiding and continuing transition processes.

The transition management (TM) approach is a theoretically developed and practice-focused governance paradigm that guides continuing transition processes such as the twin transition (D. Loorbach & Rotmans, 2006). In the TM approach, the primary focus is on the role of actors, as this body of research focuses on the role of frontrunners. Frontrunners are individuals who can create and operate within deviant structures and contribute to the generation of dissipative structures. Examples of frontrunners can be champions, policy entrepreneurs or intermediaries (Avelino & Wittmayer, 2016). These frontrunners exert distributed leadership in collectively guiding transition processes through problem-structuring and envisaging multi-stakeholder settings, coalition building, agenda implementation in experiments, and process evaluation and monitoring (D. Loorbach & Rotmans, 2006, 2010). Furthermore, the TM approach relies on the hypothesis that under specific systemic circumstances, particular types of players can significantly affect the direction, speed, and path of changes through co-creation.

Following the TM approach, actors significantly guide the twin transition (D. Loorbach, 2010). A broad range of actors is expected to work together in a coordinated way as the creation of innovation-facilitating socio-technical transitions towards sustainability require engagement in interaction, cooperative activities, and problem-solving of a broad range of actors (Kivimaa, 2014; Markard et al., 2012). An essential actor in accelerating and facilitating transitions are the intermediary actors, as intermediaries perform numerous significant activities or roles in transitions (Gliedt et al., 2018; Kivimaa et al., 2019; Mignon & Kanda, 2018; van Lente et al., 2003). It is recognized that intermediaries play a variety of significant functions in helping niches in developing and strengthen (Hargreaves et al., 2013). Intermediaries can detect similar challenges and problems faced across several local projects. By sharing this information more broadly, intermediaries may promote niche growth and distribution and allow successful efforts to profit from the knowledge they have gathered (Hargreaves et al., 2013). These activities and roles are grouped into brokering, facilitating, and configuring activities (Kivimaa, 2014). However, these activities and roles differ slightly between the diverse range of organisations, such as brokers, consultants, innovation/research centres, science parks, agencies, and research and technology organizations (RTOs) that belong to the group of intermediaries. Especially RTOs are crucial for managing the twin transition as RTOs are identified as a significant element of a country's innovation system (Charles & Stancova, 2015; Giannopoulou et al., 2019). This is because their primary goal is to produce, combine, and bridge verse forms of knowledge, skills, and infrastructures to deliver various research and development activities in cooperation with public and industry partners of all sizes. These actions produce technological, social, and systematic innovations that have an influence on the economy, society, and policies positively and reciprocally (*About RTOs | EARTO*, n.d.; van Lente et al., 2003). RTOs operate exclusively between science and industry, facilitating knowledge transfer from science base to firms (van Lente et al., 2003). RTOs' technological contributions span various domains of scientific research, encompassing a wide range of activities from fundamental research to the creation of novel goods and services. Due to this unique position, RTOs bridges the gap between the green and digital transition, which enables RTOs to effectively facilitate the integration of both domains, fostering collaboration and synergy.

Nevertheless, research on the potential of RTOs in connection with sustainability transitions is somewhat limited as current research is primarily based on RTOs' potential contribution to innovation in essential sectors of a national economy (García-Vega & Vicente-Chirivella, 2020; Hargreaves et al., 2013; Intarakumnerd & Goto, 2018; Kang, 2021; Kivimaa et al., 2019). Additionally, existing research focuses on

the motivating part RTOs play in encouraging collaboration between various actors in an innovation system, as the literature indicates that RTOs increased their collaboration with a broad range of actors to strengthen the competitiveness of their nations further through innovation which led to a positive impact of innovation performance (Fudickar & Hottenrott, 2019; García-Vega & Vicente-Chirivella, 2020; OECD, 2022; Sharif & Baark, 2011; Yu & Lee, 2017). Nevertheless, the current body of literature indicates a notable gap in academic research concerning the establishment, operations, and roles of RTOs, particularly concerning the intersection of green and digital domains (García-Vega & Vicente-Chirivella, 2020; Intarakumnerd & Goto, 2018; Kang, 2021; Sharif & Baark, 2011).

Since RTOs possess the potential to contribute to the sustainability transition and, consequently, the twin transition, it is interesting to explore the contribution of RTOs in the management and governance of the twin transition. To examine the extent to which RTOs can actively guide and stimulate the twin transition, the transition management (TM) approach mentioned above is used. This approach focuses on guiding and facilitating transitions through a participatory and collaborative decision-making process by influencing governance actions that speed the change towards sustainable goals (D. Loorbach, 2010; D. Loorbach & Wijsman, 2013). Therefore, the TM approach gives insights into RTOs governance to the twin transition. This research investigates and evaluates the extent of RTOs' contribution in actively guiding the twin transition. In doing so, the following research question is addressed:

How can Research and Technology Organizations (RTOs) contribute to the governance of the twin transition?

This research used the transition management (TM) approach to address the abovementioned problem. The TM approach is part of the sustainability transitions literature in which the role of intermediaries is acknowledged as influential (Kivimaa et al., 2019; Mignon & Kanda, 2018; van Lente et al., 2003). Especially, RTOs play a pivotal role in a nation's innovation system. RTOs are intermediary actors that drive innovation and foster collaboration between academics, the industry and the government and are recognized as critical contributors to technological advancements and economic growth (Charles & Stancova, 2015; Giannopoulou et al., 2019). So far, limited attention has been paid to the role of intermediaries, especially RTOs, in the context of the twin transition. Furthermore, the twin transition has been recently incorporated into the European Union vision, indicating the formulation of policies concerning the twin transition. However, there is a lack of understanding regarding the practical implementation and realization of the twin transition. By examining the contribution of RTOs to the governance of the twin transition, this research scientifically contributes to the existing literature by investigating the twin transition context from an intermediary perspective and by representing one of the initial endeavours that elucidate the influential role of intermediaries at which guidance on implementing the twin transition is provided.

This research investigates the contributing role of RTOs in the governance of the twin transition. RTOs are recognized as influential actors in governing the twin transition. However, more attention needs to be paid to RTOs contribution to this. However, the need for a governance paradigm focusing on guiding and continuing the twin transition is necessary as it is envisioned that the twin transition will facilitate sustainable digital transformation and strengthen sustainability with technology (Muench et al., 2022; Somers, 2022). Therefore, this research provides significant societal contribution by identifying and comprehending various roles assumed by RTOs concerning the governance of the twin transition. This offers a profound understanding of the roles of RTOs, which is beneficial for other RTOs as

recommendations are given on how RTOs could create and increase this contribution. Furthermore, this research provides valuable insights for other stakeholders engaged in the governance of the twin transition by identifying the specific roles performed by RTOs and those that are not. Which helps identify areas where other stakeholders can fill roles that RTOs may not fulfil.

To answer the research question stated above, the research is structured as follows: Section 2 provides an in-depth exploration of the concept of the twin transition, encompassing both the sustainable and digital transitions, followed by an explanation of their convergence. Section 3 delves into the transition management approach employed in this study and the operationalization of the theoretical constructs used. Section 4 of this study provides a comprehensive description of the data collection and analysis methods, rooted in a qualitative approach and conducted within a single case study focusing on a Dutch RTO. Section 6 provides a conclusion based on the contribution of RTOs to the governance of the twin transition. Lastly, Section 7 addresses the scientific and policy implications of the research conducted and describes the limitations of the research while also offering suggestions for future research directions.

2. THE TWIN TRANSITION

The following section offers separate descriptions of the sustainability transition and the digital transition, followed by an exploration of the twin transition, representing the convergence and integration of both transitions and their policy vision.

2.1. THE SUSTAINABILITY TRANSITION

Research on the effects of climate change commenced approximately a century ago, and since then, concerns and interest in sustainability have grown (Meadows et al., 1972). With the term ‘sustainable development’ coming into use, the concept, which had been developing over time, saw a significant increase in popularity. Sustainable development was described as ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs’ in the 1987 Brundtland report ‘Our Common Future’ by the World Commission on Environment and Development (Brundtland, 1987). From this definition, it becomes clear that the main goal is to satisfy human needs. However, this definition does not explicitly guide companies on which environmental components should be protected to ensure sustainable business operations. Consequently, Elkington’s (1999) operationalization of sustainability received significant attention. He introduced the concept of the triple bottom line, which organizations must adopt to be recognized as sustainable. The triple bottom line encompasses three dimensions: social, environmental, and economic sustainability (Elkington & Rowlands, 1999). The social line refers to using business methods that are fair and advantageous to the workforce, human capital, and community. The economic line refers to how the organization’s business actions affect the financial system. The environmental line refers to following procedures that do not deplete the environment’s resources for future generations (Elkington & Rowlands, 1999). This research focuses on the environmental dimension of sustainability, with relatively less emphasis on the economic and social sustainability aspects.

Sustainability has gained increasing attention as we face fundamental sustainability challenges in several domains. The social difficulties posed by current environmental problems, such as climate change, biodiversity loss, and resource depletion, are enormous (F. W. Geels, 2011). Therefore, sustainability transitions are required, which are fundamental, multifaceted, long-term transformation processes that enable established socio-technical systems to adopt more environmentally friendly production and consumption practices (Markard et al., 2012). Sustainability transitions are goal-oriented in addressing persistent environmental problems to address grand challenges in a way that satisfies current demands without jeopardizing the capacity of future generations to satisfy their own needs (Markard et al., 2020). The essence of sustainability transitions is to profoundly alter how we govern and arrange our societies and economies, which entails turning away from behaviour and technologies that are not sustainable and turning towards sustainable options that advance social, economic, and natural well-being (F. W. Geels, 2011; Kates & Parris, 2003). The focus on sustainability transitions is now more critical than ever, as the most recent IPCC report evidenced that global warming already has profound and partially irreversible effects on the earth, which makes it more crucial than ever to achieve long-term sustainability goals, which requires changes in societal standards and ideals, as well as technical, institutional, and behavioural changes (IPCC, 2022).

2.2. THE DIGITAL TRANSITION

In addition to the growing emphasis on sustainability transitions, another notable trend that has rapidly emerged over the past three decades is digitalization, leading to digital transformation. Throughout the years, three different phases of digital transformation have been identified: digitization, digitalization, and

digital transformation (Verhoef et al., 2021). Digitization involves converting analogue data into a digital format to enable computer storage, processing, and transfer. Research also recognizes it as transforming from analogue to digital tasks (Verhoef et al., 2021). Digitalization is the process of modifying current business processes using IT or digital technologies. By altering current business operations, such as communication, distribution, or business relationship management, IT is a critical enabler in digitalization to capture new business opportunities (Li et al., 2016; Verhoef et al., 2021). Digital transformation is the most prevalent phase and denotes a transformation of the entire organization that creates new business models, some unique to the target company or sector. Beyond digitalization, which is the modification of straightforward organizational procedures and duties, digital transformation influences the entire firm and its business practices (Iansiti & Lakhani, 2014; Kane et al., 2015; Pagani & Pardo, 2017).

During the early phases of digital transformation, digital technology was primarily perceived as a mere facilitator for business operations. Nowadays, there is often no meaningful distinction anymore between business and IT strategy, as they have become closely intertwined. This transformative shift in business culture and operations has resulted in a new era characterized by the pervasive adoption of advanced technologies. This era is commonly referred to as Industry 4.0, which symbolizes the increased integration of smart technologies into various industrial domains (Oláh et al., 2020). The emergence of digital technologies has brought significant changes in how businesses and individuals conduct their daily activities, resulting in a digital transition. The concept of the digital transition entails the shift from analogue to digital processes, enabling the utilization of digital tools to model and enhance various activities, ultimately leading to improved performance and productivity (Rosário & Dias, 2022).

Furthermore, the digital transition has enhanced the capacity to develop and implement sustainable solutions (Rosário & Dias, 2022). The primary force behind industrial change is the digital transition, which refers to the adoption of technologies like intelligent systems, automation and robotization, sensor networks, the Internet of Things (IoT), cloud, software, platform and infrastructure as a service, analytics, big data, artificial intelligence, and distributed ledger technologies, which transforms business operations, environments, and strategies (Komninos, 2022). Additionally, this transition is generally linked to developments in big data analytics, the acceptance of digital technologies, and a rise in its utilization (Satalkina & Steiner, 2020). Consequently, digital transformation encompasses the incorporation of digital technologies. In contrast, digital transition entails strategic progressions that necessitate substantial changes in structure and procedures during the transition from one technology to another (Almatrodi & Skoumpopoulou, 2023; Rosário & Dias, 2022). The digital transition is considered significant but also required for various reasons. One of the reasons is the increasing need for digital connectivity, especially in the context of the Internet and the rise of e-commerce. The digital transition has also been driven by the need to improve efficiency and productivity, reduce costs, and enhance the user experience. Other reasons include improving access to information, reducing environmental impact, and enabling more significant innovation (Rosário & Dias, 2022; Satalkina & Steiner, 2020).

Moreover, the literature on digital transitions indicates that the digital technologies that are part of the digital transition process are increasingly deployed in improving environmental sustainability and can provide a solution for more sustainable and effective environmental management (X. Wang et al., 2015; Y. Wang et al., 2015). The digital transition could accelerate the process of lowering carbon emissions and link people globally, fostering international cooperation and a feeling of urgency to address environmental issues (Lichtenthaler, 2021). Due to this, the digital transition may significantly speed up the process of attaining sustainable development.

Nevertheless, the increase of digital technologies within the digital transition can worsen social and environmental divisions as concerns surrounding the adverse effects of digital technologies on the environment arise (Lichtenthaler, 2021). This is because the digital discourse emphasizes the adverse effects of technology's extensive use in the context of toxic waste products, resource utilization, carbon dioxide (CO₂) emissions, high levels of energy consumption, and greenhouse gas emissions (Dwivedi et al., 2022; Linkov et al., 2018). It is further mentioned that digital infrastructures and devices, such as blockchain or smartphones, require large amounts of energy, which counteracts the goals of an environmentally stable development (Lenz, 2021). As a result, there is increasing concern that digital technologies will make the effects on the environment even worse, although digital technological breakthroughs are strongly related to delivering solutions to global warming (Dwivedi et al., 2022; Lenz, 2021; Lichtenthaler, 2021; Linkov et al., 2018; Rosário & Dias, 2022). In addition to the environmental challenges that are caused by increasing digitalization, it also raises potential challenges to social well-being. For example, the advantages or drawbacks that innovative digital technologies have for social networks and lifestyles, such as risks to economic viability and the widening of economic inequality (Linkov et al., 2018).

2.3. CONVERGING GREEN AND DIGITAL TRANSITIONS

Despite the adverse effect of digital technologies on the environment, the digital transition is still considered promising in developing and implementing sustainable solutions (Rosário & Dias, 2022). This leads to the fact that the sustainable and digital transitions are two of the main dominant processes of societal change, as it is inconceivable to envision a time without digital technologies or in one in which sustainability themes are no longer significant (Dwivedi et al., 2022; Lenz, 2021). After an extended period throughout which the sustainability and digital transition have run parallel, they are beginning to converge as the integration of digitalization with sustainability is seen as a fruitful combination (Lenz, 2021). It is even stated that digitalization is to be one of the most promising transformations for sustainability, as it may contribute to higher levels of sustainability (Del Río Castro et al., 2021; Lichtenthaler, 2021; Sareen & Haarstad, 2021; Stuermer et al., 2017). Consequently, the convergence of the digital and green transitions is extensively explored in academic literature, highlighting their synergies and potential to enhance their overall effectiveness and impact (Muench et al., 2022; J. Smith et al., 2018).

Converging the green and digital transition is considered critical for achieving sustainable development goals and addressing the urgent challenges of climate change, resource depletion, and social inequality (Barth & Lang, 2023; István, 2020; Muench et al., 2022; J. Smith et al., 2018). Therefore, current academic literature predominantly emphasizes the role of the digital transition in reinforcing the sustainability transition, as digitalization is seen as a significant enabler or contributor to the sustainability transition. Since the digital transition helps accelerate the sustainability transition by enabling more efficient use of resources, reducing waste, and enabling the development of new sustainable technologies and business models (Muench et al., 2022; J. Smith et al., 2018). With the aid of digital technologies, industries can become more sustainable in several ways, including by implementing the necessary organizational changes at the corporate level to boost sustainability performance, by enhancing organizational planning processes to aid in predicting demand and identifying sustainability-related opportunities, and by enabling companies to test out creative and affordable business models (Rosário & Dias, 2022). Organizations must enhance their knowledge of and adapt their production processes if digital technologies are to be sustainable. Consequently, a significant body of literature explores the convergence of green and digital domains, particularly emphasising digitalisation's enabling role in advancing sustainability objectives.

Academic research on the reinforcement of digitalization by sustainability is relatively scarce, with most existing literature suggesting even a negative impact on the sustainability aspects of digital technologies.

Although the digital transition processes are increasingly mentioned as a critical contributor to sustainability transitions, it is evident that not all technological advancements lead to greater sustainability and that some difficulties exist when combining the digital and green transitions (Mäkitie et al., 2023). For example, the emissions produced by the usage of cryptocurrencies are noticeable, as are the massive carbon emissions and considerable water and land footprints left by data centres. From this, certain digital technologies may reinforce already-in-place potentially unsustainability practices, thus hindering sustainability transitions, while other technologies may support sustainability transitions (Mäkitie et al., 2023).

Despite the extensive focus on connecting the digital and green transitions in the literature, the practical integration of these transitions has yet to be widespread. In reality, the two transitions are still too often considered in isolation, resulting in the sustainability transition to fully leveraging the potential of the digital transition. However, this is considered necessary as problems such as anthropogenic climate change, poverty, high rates of species extinction, and lack of equal opportunities continue (Rosário & Dias, 2022). Therefore, more emphasis should be placed on converging the green and digital transitions.

2.4. TWIN TRANSITION: A POLICY VISION

As mentioned earlier, significant scholarly interest has been in connecting sustainability and digital transitions in academic literature throughout the years. However, in reality, the convergence of these two transitions is still in its early stages, as they are often viewed and addressed separately. This fragmented approach hinders the rapid achievement of sustainability targets. Therefore, the European Commission (EC) has established the goal to use digital technologies to pursue a green future through systemic transformation by presenting the concept of twin transitions, which is visualized in Figure 1. The twin transition is a simultaneous, linked green and digital transition to reduce companies' carbon footprint (Rehman et al., 2023). Figure 1 visually represents the twin transition, illustrating the interconnection between the digital and sustainability transitions. As depicted in the figure, the digital transition enables the green transition by utilizing information technology (IT) and data. Additionally, the greening of IT and data is also observed within this intertwining process, implying that both transitions reinforce each other. The twin transition is crucial to achieving the EU's goal of becoming climate neutral by 2050 and transforming Europe into a globally competitive climate-neutral economy (István, 2020). This is because combining the digital and sustainability transitions enables more efficient use of resources, reduces environmental impacts, and creates new opportunities for innovation and economic growth (István, 2020). It is, therefore, essential to unleash the potential of digitalization while also putting sustainability at the center of digital transformation (European Digital SME Alliance, 2020).

Following the EU's new growth strategy, the European Green Deal, which will be essential to constructing long-lasting and successful growth, speeding the twin digital and green transitions has been assigned as a European priority. The EU Green Deal is comprehensive and addresses all aspects of activity, including the environment, energy, transportation, business, and industry. It proposes a development strategy to address these issues and make the EU a just and prosperous society with a competitive economy that is modern, resource-efficient, and emits no greenhouse gases by 2050 (Komninos, 2022). It also describes

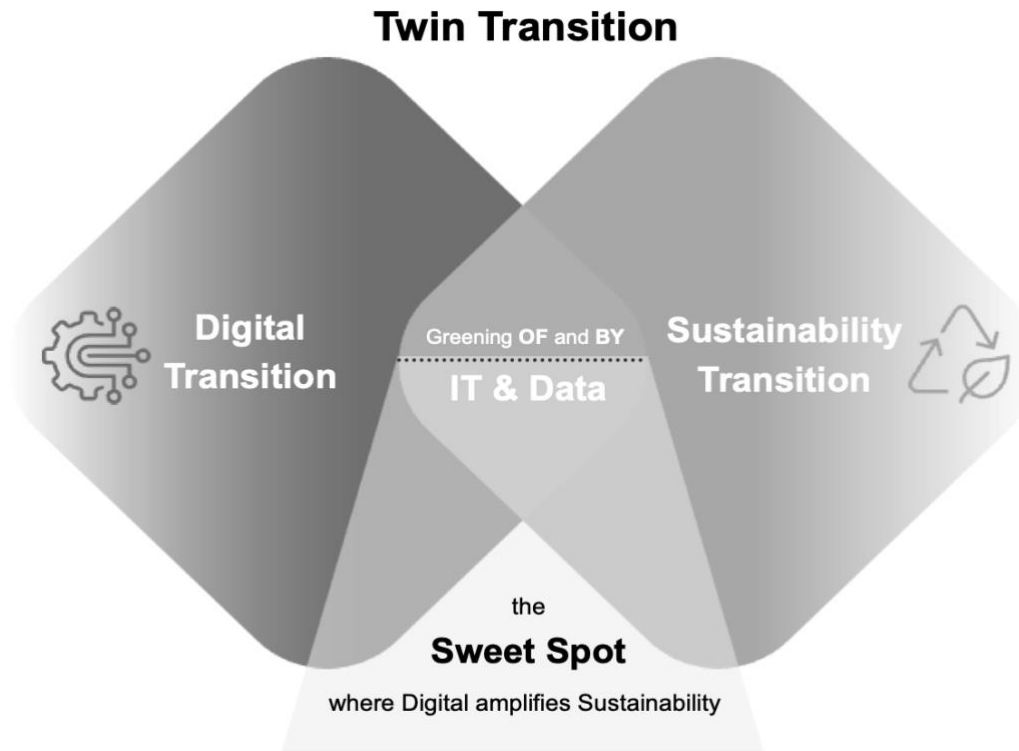


Figure 1. The moment of the twin transition when sustainability is amplified by digital (Blüm, 2022).

how to decouple economic growth from resource usage. The EC asserts that to achieve EU Green Deal goals, Europe must use the potential of digital transformation (Ortega-Gras et al., 2021). Therefore, the EU's policy vision for the twin transition arises from the European Green Deal and the accompanying EU's digital strategy (European Commission, 2023). At the same time, the EU's digital strategy aims to ensure that the EU is at the forefront of digital transformation while ensuring that this transformation is sustainable and inclusive. The EU member states are essential to the EU's digital strategy. While the European Commission is responsible for developing and implementing policies to achieve the strategy's goals, member states are key partners in delivering on the goals of the EU's digital strategy (European Commission, 2019).

Political decision-makers are also addressing the challenge of uniting the digital and sustainable transitions in the twin transition (Lenz, 2021). For example, in the report *'Driving the Green and Digital Twin Transition'* from the European Union (Interreg Europe, 2021) and in the report *'Digitalization as a key enabler for a resilient and sustainable energy ecosystem'* from Digital Europe (DIGITALEUROPE, 2023) with these reports European Union policy-makers are trying to integrate digitalization and sustainability in policy objectives. In addition, there are also several reports from European countries to create a digitalization strategy that combines growth and environmental protection (Lenz, 2021). However, the twin transition is currently mainly described conceptually, and it still needs to be clarified what it exactly means when the digital and green transition are twinned in practice. However, several initiatives focus on the contributing role of digital technologies to sustainability and vice versa. Some examples of these initiatives are the European Green Digital Coalition (EGDC), a European research network called 'Digitalization for sustainability – Science in Dialogue' (D4S), Energy Innovation NL focuses on linking digitalization with sustainability, and the Club of Wageningen (Club van Wageningen, n.d.; Drupal, 2023; European Digital

SME Alliance, 2020; Lange et al., 2023). Besides the existing initiatives to link digital and sustainability issues, there is also a focus on making digitisation sustainable. An example of such an initiative is the National Sustainable Digitisation Coalition (NCDD)(Woutersen, 2023).

The Netherlands aims to achieve the Sustainable Development Goals (SDGs) by 2030. To this end, the government led multiple transitions in which digital applications already play a significant role, for example, in the mobility sector. Here digital technologies are used to obtain data on various topics, which can be used to improve the traffic flow and reduce CO₂ emissions (RLI, 2021). Despite this focus on digital applications, there still needs to be more systematic thinking in government policy about how the digital transition is fundamentally changing the economy and society (RLI, 2021). Furthermore, there needs to be more systematic consideration of how digitalization should be guided to achieve a transition towards a sustainable society. Consequently, there needs to be more comprehensive information on the governance and management of the twin transition, indicating the need for further exploration of the governance of the twin transition. To examine the governance of the twin transition, the study employs the transition management (TM) framework. The TM approach, known for its theoretical foundation and practical application, offers a governance paradigm that can effectively guide ongoing transition processes, including the twin transition. The TM approach is an approach within the field of sustainability transitions. The subsequent section provides a comprehensive discussion and exploration of this approach.

3. THEORY

As mentioned earlier, this section offers a thorough and in-depth examination of the transition management (TM) approach within the field of sustainability transitions. It provides a comprehensive discussion and exploration of the key concepts and principles associated with the TM approach.

3.1. THE FIELD OF SUSTAINABILITY TRANSITIONS

A transition is a fundamental shift in a social (sub) system's structure, culture, and practices resulting from the co-evolution of ecological, institutional, cultural, and technical advances at various scale levels. Transitions are highly complex, last for 25 to 50 years, and include many different stakeholders and sectors (Bosman & Rotmans, 2016; D. Loorbach et al., 2017; Rotmans & et al., 2001; Silvestri et al., 2022). The social difficulties posed by current environmental issues show that the change processes must be oriented towards more sustainable system states (Frantzeskaki et al., 2012). Therefore, so-called sustainability transitions are initiated to fundamentally restructure consumption and production systems (Farla et al., 2012).

Sustainability transitions are long-term, multi-faceted, and fundamental transformation processes that enable socio-technical systems to change their production and consumption patterns in favor of more environmentally friendly ones (Markard et al., 2012). Sustainability transitions research aims to understand how societies transition to more sustainable ways of living. Four common approaches in this field are the multi-phase concept, the multi-level perspective (MLP), strategic niche management (SNM), and transition management (TM). The multi-phase concept approach focuses on the various stages a society or system goes through during a transition to sustainability. This approach assumes that transitions occur in multiple stages, each with distinct characteristics and challenges (F. W. Geels, 2002; Markard et al., 2012). The MLP approach considers sustainability transitions as processes that occur at multiple levels of society, including the technological, institutional, and cultural levels. According to the MLP, the interaction of the three analytical levels – macro, meso, and micro – leads to transitions. (I. F. W. Geels, 2005; A. Smith et al., 2005). The SNM approach focuses on the role of ‘niches’ or protected spaces for unsustainable innovation to develop and mature (Raven & Geels, 2010). These niches provide a supportive environment for experimentation and learning and eventually lead to the diffusion of innovation into the wider society. SNM involves identifying and supporting these niches and creating linkages between them and the wider society to facilitate diffusion (Raven & Geels, 2010). Finally, the TM approach is a governance approach that focuses on facilitating and guiding transitions towards sustainability through a process of participatory, collaborative decision-making. This approach emphasizes the importance of building social and political support for sustainability transitions and the need to address multiple dimensions of sustainability in a coordinated way (D. Loorbach, 2010). TM involves identifying and prioritizing sustainability goals, developing roadmaps for achieving those goals and implementing and monitoring policies and practices to support the sustainable transition (Frantzeskaki et al., 2012; D. Loorbach, 2010).

Governance constitutes the totality of interactions involving both public and private actors. Therefore, transition governance builds on the idea that actors influence the transition processes. The importance of agency in transition, particularly on how the agency could impact the speed and direction of transitions, and ultimately how such agency might be promoted to contribute to sustainable transitions, play a vital role in transition governance (D. Loorbach et al., 2017). The foundation of transition governance is the idea that the network society offers a variety of methods for actors to organize themselves to generate answers to societal challenges. Transition governance then seeks to influence how actors do this and how different

types of agencies add up to answer these societal challenges (D. Loorbach et al., 2017). This focus on governance within the TM framework is considered relevant for studying the twin transition, as it is still in its early phases. It implies several actors must organize themselves to put the twin transition in the right direction.

Additionally, one of the main challenges in the field of sustainability transitions is to improve the understanding of the policies and politics in transitions (Markard et al., 2012; Rogge & Reichardt, 2016). Transition governance is required to understand this as achieving sustainability transitions necessitates a collaborative and participatory strategy, engaging numerous partners from various sectors and levels of governance (Rogge & Reichardt, 2016). Furthermore, given the TM's emphasis on collaboration, stakeholder involvement, long-term thinking, flexibility, and learning, the TM framework is selected as the most appropriate theoretical framework for this study in preference to the other three approaches (D. Loorbach, 2010). This choice is also based on the framework's alignment with the research objectives and the potential to provide valuable insights into the governance of the twin transition, as the TM framework is a governance approach. The selection of the TM framework as the most appropriate approach is further supported by its suitability for managing complex and long-term transitions. The twin transition involves dual transitions and is therefore considered complex, making the TM framework particularly well-suited for studying its dynamics. Additionally, little attention has been paid to dual transitions in the field of sustainability transitions. The TM framework has only been used to this point in industries that are defined by different environmental subsystems, such as power, water, and transportation (Stephens & Graham, 2010). These considerations support the appropriateness of adopting the TM framework as the most suitable approach for this study.

An updated framework that builds on the TM framework, namely the x-curve framework, exists. The x-curve framework aims to increase the awareness of transition dynamics and assist society actors in navigating them (Hebinck et al., 2022). It demonstrates linkages between the processes of build-up and breakdown and assists in comprehending and creating governance strategies for sustainability transitions (Hebinck et al., 2022). The main difference between the x-curve and the TM framework is that the x-curve considers the breakdown dynamics, including the destruction part of a transition (Hebinck et al., 2022). As the twin transition is still in the early phase of its realisation, the build-up, especially the breakdown patterns, will be challenging to capture or not even present. Therefore, the TM framework was chosen above the x-curve in this research.

3.2. DEFINING ACTORS IN SUSTAINABILITY TRANSITIONS

Besides the four common sustainability transition approaches, various actors must engage in interaction, cooperative activities, and problem solutions to generate innovation-facilitating socio-technical transitions towards environmental sustainability (Kivimaa, 2014). Many different types of actors are involved in this process, at which intermediary actors are considered most highly essential in accelerating and facilitating transitions (Gliedt et al., 2018; Kivimaa et al., 2019; Mignon & Kanda, 2018; van Lente et al., 2003). Therefore, intermediary actors are recognized as vital stakeholders in sustainability transitions, making them the focal point of this research. Intermediaries are defined as “actors that positively influence sustainability transition processes by linking actors and activities, and their skills and resources, or by connecting transition visions and demands of networks of actors with existing regimes in order to create momentum for socio-technical change, to create new collaborations within and across niche technologies, ideas and markets, and to disrupt dominant unsustainable socio-technical configurations” (Kivimaa et al., 2019, p. 1072).

It is widely acknowledged that intermediaries are essential players who speed up the innovation process, encourage eco-innovation, and assist transitions and sustainable entrepreneurship through playing a variety of responsibilities (Kant & Kanda, 2019). The role of intermediaries in facilitating innovation and sustainability transitions is one of the aspects of intermediaries that have received the most investigation. However, intermediaries are said to play a variety of roles, such as articulation of needs and requirements, project management, managing external resources and organizational development, foresight and diagnostics, knowledge processing and combination/recombination, gatekeeping, brokering, testing and validating, accreditation, validation, and regulation (Howells, 2006). The roles of intermediaries are grouped into three functions (Kant & Kanda, 2019; Stewart & Hyysalo, 2008). These functions are facilitating, which means providing opportunities and space for other people to act. Configuration, which means adjusting the material and symbolic form of technology, often in minor ways and how it is interpreted and used, and finally brokering, which means establishing, nurturing, adjusting and altering connections between different actors (Stewart & Hyysalo, 2008).

Many different intermediary actors exist, all performing slightly distinct roles. They vary from specialized private businesses offering consultancy and research services to university technology transfer departments (van Lente et al., 2003). An influential intermediary actor is research and technology organizations (RTOs) which are defined as “specialized knowledge organizations dedicated to the development and transfer of science and technology to the benefit of the economy and society” (*About RTOs | EARTO*, n.d., p.3). RTOs are dedicated to utilizing science and technology to drive innovation, support public bodies and industry, and enhance the quality of life while promoting economic competitiveness (Charles & Stancova, 2015). RTOs combine new types of knowledge as they have access to extensive and diverse information and are therefore identified as essential elements or key agents of a country’s innovation system (Charles & Stancova, 2015; Giannopoulou et al., 2019). Given their potential significance, it is essential to assess the contribution of RTOs to the governance of the twin transition. Hence, it is imperative to examine the diverse roles assumed by RTOs in the context of the twin transition and compare them with the existing roles of intermediaries discussed earlier. Moreover, the selection of RTOs as the primary focus in this study reinforces the rationale behind selecting the TM framework, as it emphasises the active role of actors in the governance of a transition (D. Loorbach, 2010). The subsequent section elaborates on the concept of TM.

3.3. TRANSITION MANAGEMENT

The concept of transition management (TM) was introduced as a new governance approach for sustainability transitions (D. A. Loorbach, 2022). TM is a comprehensive approach and analytical framework to influence governance activities, leading to accelerated change toward sustainability ambitions. TM operates at multiple scales and involves multiple actors, taking a long-term and process-oriented perspective. Its primary aim is to deepen our understanding of social system transformations and actively promote and facilitate them (D. Loorbach, 2010; Stephens & Graham, 2010). TM created an approach of governance that fundamentally challenges and eventually tries to replace traditional (market and governmental) institutions, structures, attitudes, and practices that now support unsustainable social regimes (D. A. Loorbach, 2022). The goal of TM is to challenge, change, and replace existing unsustainable regimes while also investigating desired possible future transitions more practically (D. A. Loorbach, 2022).

The TM framework serves two purposes: an intervention, management, and governance approach for initiating transitions and an analytical framework for exploring and comprehending transitions. It can be utilized prescriptively, offering guidance for shaping policy processes, implementation, and evaluation and, descriptively, providing insights into the evolution of transitions (Stephens & Graham, 2010). However, most research on transition management is driven by a practical motivation to facilitate the transition towards a more sustainable state. Numerous studies have investigated and assessed the results of transition management projects across several industries, frequently using an action research approach. These practical experiences have offered insightful information that may be used to build conceptual frameworks and processual methods that can be used as instruments in policy-making. Examples of such studies include the work of Kemp et al. (2007), Kern and Howlett (2009), Kern and Smith (2008), and Loorbach and Rotmans (2010), among others. Academic research that descriptively utilises the TM framework is relatively limited. An example of such a study is the work of Stephens and Graham (2010). This study also descriptively employs the TM framework, providing insights into the evolution of transitions. This approach is particularly relevant in the context of the twin transition, which is still in its early stages of development. Although the elements of the TM framework have a more significant potential for prescriptive insights, the TM framework also offers a useful distinction among four types of governance or management activities in the descriptive realm (Stephens & Graham, 2010).

These four types of governance activities are (1) strategic activities, (2) tactical activities, (3) operational activities, and (4) reflexive activities (D. Loorbach, 2010). Strategic activities involve visioning, setting long-term goals, having strategic conversations, and establishing the framework for social change. For the redefinition of shared visions and goals, leadership ability, long-term focus, and integrated tactics are required. Strategic activities are all the initiatives and changes that focus primarily on the 'culture' of a social system (D. Loorbach, 2010). Tactical operations are seen as steering activities that frequently alter current organizations, structures, and institutions to make it easier for them to carry out more significant strategic objectives (Stephens & Graham, 2010). This encompasses all established routines and patterns, including rules and regulations, institutions, networks, and organizations. So, this activity encompasses all players involved in daily program development, financial and institutional regulation and frameworks, network and coalition building, and, more generally, representing particular interests (D. Loorbach, 2010). Operational activities are viewed as short-term experiments typically conducted in the framework of innovation initiatives and programs, business and industry, politics, or civil society. These actions and experiments are called 'innovation' (D. Loorbach, 2010). Finally, monitoring, evaluating, and assessing current policies and ongoing societal development are all reflexive activities (D. Loorbach, 2010). Reflexive activities, which are connected to the other three categories, are essential to avoid lock-in and to promote the exploration of novel concepts and paths (D. Loorbach, 2010). According to the TM framework, strengthening actions focused on change and enhancing or accelerating a transition may be accomplished by creating strong connectivity across strategic, tactical, operational, and reflexive activities (D. Loorbach, 2010; Stephens & Graham, 2010).

For each activity, specific practices, also known as practical governance tools, have been created (D. Loorbach, 2010; D. A. Loorbach, 2022). To execute the TM strategy, these tools were created based on the characteristics of the four activities and recorded in a cycle process model. This cyclical process, known as the TM cycle provides the viewpoint of actively influencing social self-steering and governance activities (D. Loorbach, 2010). In Figure 2, the TM cycle is visualised, at which the governance tools of problem structuring, the establishment of the transition arena and envisioning belong to the strategic activities. Developing coalitions and transition agenda belong to the tactical activities. The governance tools of

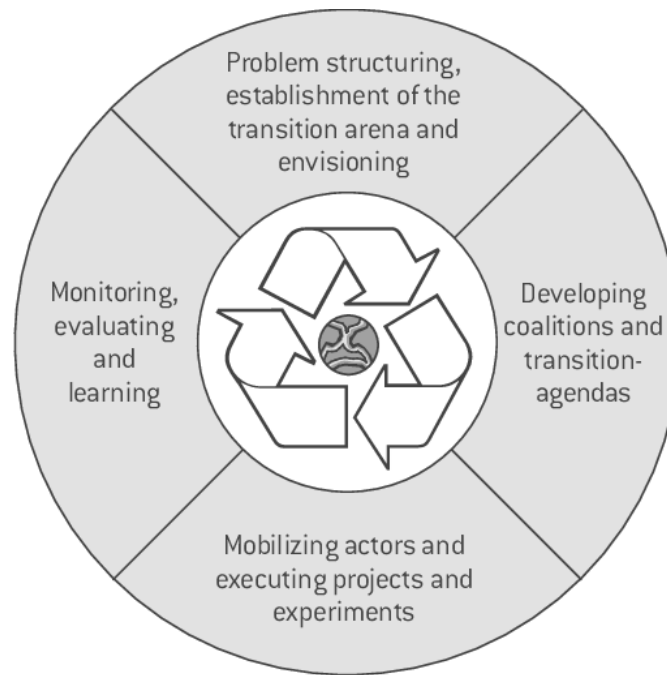


Figure 2. Transition management cycle (D. Loorbach, 2010).

mobilizing actors and executing projects and experiments belong to the operational activities, and finally, the monitoring, evaluation and learning tools belong to the reflexive activities (D. Loorbach, 2010). The governance tools visualized in Figure 2 are encompassed within four fundamental components: the transition arena, the transition agenda, transition experiments and transition monitoring. The following subsections provide detailed explanations of each of these four governance tools.

3.3.1. TRANSITION ARENA

The transition arena, a small network of frontrunners with diverse competencies, interests and backgrounds, is at the centre of the TM and has a pivotal role (D. Loorbach & Rotmans, 2006). The frontrunners active in the transition arena are individuals with specific competencies and innovative ideas or practices about a persistent problem which are considered vital for transition processes (D. Loorbach & Rotmans, 2010; D. Loorbach & Wijsman, 2013; Wittmayer et al., 2017). In the context of this research, the focus is on one specific frontrunner, namely RTOs. The transition arena might be utilized in various ways at once to create new content (ideas, agendas and visions), assist the formation of networks and coalitions, foster learning, and subtly influence current governments or regime players (D. Loorbach & Rotmans, 2010). Additionally, the transition arena could create a space to share ideas in which processes move along different phases in which the network of frontrunners could structure problems and develops common visions, strategies, and actions for sustainability transitions (D. Loorbach, 2010; D. Loorbach et al., 2017; Roorda et al., 2014).

When the transition arena is established, an effort should be made to arrive at a shared perspective of the issues through a highly participatory process in which RTOs could be involved (D. Loorbach, 2010). Sustainability visions are developed based on this shared perspective through interaction and discussion. These visions primarily include the basic long-term development principles that are agreed upon, leaving room for dissent upon short- and medium-term solutions, objectives, and strategies (D. Loorbach, 2010). Visions are a vital management instrument for achieving fresh perspectives and beginning points.

Given the research focus on the contribution of RTOs in the governance of the twin transition, it is crucial to operationalize the transition arena within this specific context by linking the tools to the potential roles of RTOs. Table 1 provides an operationalization of the transition arena as a governance tool in the context of this research, highlighting the specific roles and activities of RTOs within each sub-theme.

Table 1. Operationalization of the transition arena

Sub-themes	Operationalization
The establishment of the transition arena	The role of RTOs in creating a network of frontrunners with diverse competencies, interests, backgrounds and focuses on the twin transition.
Developing a shared perspective on the transition	The role of RTOs in interacting to share ideas and confront different perspectives of frontrunners.
Articulating a common vision of the transition based on a shared perspective	The role of RTOs in developing a common vision, including long-term development principles for the twin transition.

3.3.2. TRANSITION AGENDA

A shared transition agenda should be created based on the shared sustainability visions and the shared problem perception derived from the transition arena. This is significant because a collaborative transition agenda incorporates shared problem perceptions, goals, action points, projects, and instruments as opposed to each arena player bringing their own agenda into the transition arena (D. Loorbach & Rotmans, 2006). A transition agenda is a coordinated action plan for starting or advancing transformations (D. Loorbach & Rotmans, 2006). The players in the transition arena use the transition agenda as their compass as they go through the transition process. The shared transition agenda should be flexible as it is dynamic and can change over time (D. Loorbach & Rotmans, 2006).

To address the issues on the transition agenda as adequately as feasible, it must be crucial to have the means to carry out the suggested strategies. Therefore, it is crucial to establish which actors are responsible for determining the kind of project, activity, or tool to be created or used. The focus is on which activities are performed by RTOs (D. Loorbach & Rotmans, 2006). To sum up, the transition agenda serves as a compass that the participants in the transition arena should use as they navigate the change process (D. Loorbach & Rotmans, 2006).

Table 2. Operationalization of the transition agenda

Sub-themes	Operationalization
The development of a shared transition agenda	The role of RTOs in developing an agenda for the twin transition that is based on shared sustainability visions and perceptions of problems.
Determining which actors are responsible for which type of activity, project, or instrument to be developed or applied	The role of RTOs in establishing activities, projects, or instruments for the twin transition and who is responsible for them.

Given the research focus, it is crucial to operationalize the transition agenda within the context of RTOs' contribution to the twin transition. Therefore, Table 2 provides an operationalization of the transition agenda as a governance tool in the context of this research, illustrating the specific roles of RTOs within each sub-theme.

3.3.3. TRANSITION EXPERIMENTS

Transition experiments and activities are carried out at the operational level of transition management to deepen, expand, and scale up current and planned initiatives and actions (D. Loorbach, 2010). Transition experiments are well-known initiatives with a high level of risk that may have a significant inventive impact on a transition process. The determined sustainability vision and transition objectives are the direct sources of new transition experiments, which should align with the established transition paths (D. Loorbach, 2010). Making the experiments cohesive with one another should be crucial. The most important thing is to assess how much the projects and experiments contribute to the overall system sustainability objectives and how one experiment supports another (D. Loorbach & Rotmans, 2006). If there are already innovation experiments taking place, transition experiments can also be linked to these as well, as long as these innovation experiments fit into the context of the transition (D. Loorbach, 2010). Transition experiments should be carried out through the networks or arena players that already exist to ensure the direct participation of frontrunners (D. Loorbach & Rotmans, 2006).

Several types of structural uncertainty hamper transition processes. To ascertain which uncertainties are structural and which ones may be minimized, it is crucial to maintain a variety of possibilities open and investigate the nature of these uncertainties in the transition experiments (D. Loorbach & Rotmans, 2006). These uncertainties must be thoroughly investigated and mapped out during the TM cycle. Estimating these uncertainties shifts due to learning from transition experiences during the transition process. The transition visions, images and goals could then be adjusted as a result of this (D. Loorbach & Rotmans, 2006).

Given the research focus on the contribution of RTOs to the twin transition, it is essential to operationalize the transition experiment within this context. Table 3 presents such an operationalization, highlighting the specific roles played by RTOs within each sub-theme.

Table 3. The operationalization of transition experiments

Sub-themes	Operationalization
The creation of transition experiments which should be in line with the transition visions and paths	The role of RTOs in creating transition experiments that align with the transition visions and paths for the twin transition.
The implementation of experiments through already existing networks of arena participants	The role of RTOs in implementing of twin transition-focused experiments through existing arena participant networks.
The thorough investigation and mapping out of uncertainties in the transition experiments	The role of RTOs in investigating and mapping uncertainties in the transition experiments focusing on the twin transition.

3.3.4. TRANSITION MONITORING AND EVALUATION

Continuous monitoring is vital to the search and learning processes (D. Loorbach, 2010; D. Loorbach & Rotmans, 2006). Two different monitoring processes should be distinguished: monitoring the transition processes itself and monitoring transition management (D. Loorbach, 2010; D. Loorbach & Rotmans, 2006). Macro developments that are changing slowly but surely, niche developments that are developing quickly, and movements of both individual and group actors at the regime level are part of the transition process that must be monitored. This offers the "enhanced context" for transition management (D. Loorbach, 2010).

A distinct kind of monitoring is needed to monitor transition management. The transition arena's actors must first be observed concerning how they act, build alliances, network, carry out their roles, and monitor their actions, projects, and instruments. Second, the agreed-upon activities, objectives, initiatives, and tools must be monitored as they relate to the transition agenda. Next, it is crucial to keep an eye on how new information and insights are being shared, and how social and institutional learning are affected by transition experiments. Finally, it is necessary to monitor the transition process to determine its pace of progress, any barriers, and any areas that require improvement (D. Loorbach, 2010; D. Loorbach & Rotmans, 2006). A social learning process resulting from the interaction and collaboration between the various players involved may be stimulated by incorporating monitoring and evaluation into every stage and level of the transition management process and is, therefore, essential (D. Loorbach, 2010).

Given the research focus on the contribution of RTOs to the twin transition, it is essential to operationalize the monitoring and evaluation of the transitions within this specific. Therefore, Table 4 is created.

Table 4. The operationalization of transition monitoring and evaluation

Sub-themes	Operationalization
Monitoring of the transition process	The role of RTOs in monitoring developments at the macro and micro level concerning the twin transition.
Stimulation of social learning	The role of RTOs in the interaction and collaboration between the different actors concerning the twin transition while monitoring the twin transition.

3.4. CONCEPTUAL MODEL

Following the theoretical foundations of the twin transition and the TM framework, a conceptual model was developed to represent this study's key elements and relationships visually. The conceptual model, illustrated in Figure 3, encapsulates the role of RTOs in the TM framework's four theoretical constructs and represents the twin transition in which the green and digital transitions converge.

Figure 3 depicts a visual representation of the twin transition, highlighting the overall perspective in the existing literature that views the digital transition primarily as a facilitator or catalyst for the green transition. Additionally, the figure illustrates the position of RTOs within the twin transition, showcasing their intermediary role in bridging the green and digital domains. Furthermore, Figure 3 illustrates the contribution of RTOs to the four theoretical constructs of the TM framework. Within each construct,

namely the transition arena, transition agenda, transition experiments, and transition monitoring and evaluation, the specific role of RTOs is delineated.

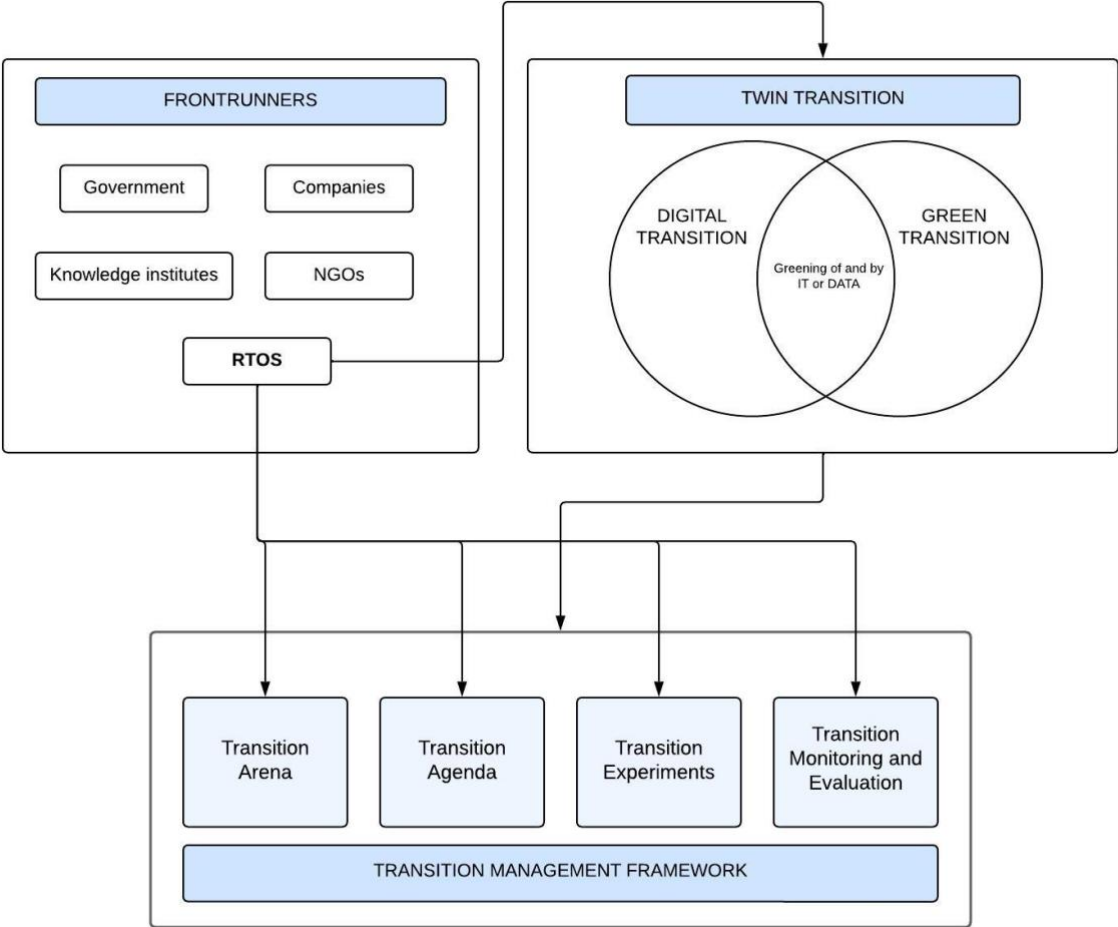


Figure 3. Conceptual model of twin transition research

4. METHODS

As the research goal is to investigate how RTOs can contribute to the governance of the twin transition, an exploratory research approach is used (J. Corbin & Strauss, 2012). A qualitative research design ensures that deep and holistic insights are provided, and it allows for a complete understanding of the contributing role of RTOs to the governance of the twin transition. The research methodology encompasses several vital components. Firstly, the case study approach and selection process are thoroughly explained, highlighting the rationale behind the chosen case and its relevance to the research objectives. Subsequently, this study's data collection and analysis techniques are detailed, emphasizing the methods used to gather and analyse the data systematically and rigorously. Finally, the reliability and validity of the research methods are addressed.

4.1. CASE STUDY APPROACH AND CASE SELECTION

A qualitative case study comprising a Dutch RTO was used to answer the research question. Qualitative case studies are well suited to respond to 'how' and 'why' questions and allow addressing the research question in-depth while leaving room for unexpected findings (Yin, 2009). More specifically, single case studies have been recognized as productive research approaches to provide a deep understanding of the exploring subject (Yin, 2009). Choosing a single case as a research design offers the understanding of a larger class of units while only intensively studying one single unit (Gerring, 2004). This provides potential for other RTOs to comprehend their involvement in the governance of the twin transition.

The Netherlands Organisation for Applied Scientific Research, TNO, was the chosen case for this research as it fulfilled the following criteria (*Organisatie | TNO*, n.d.). First, the chosen case must be an established RTO that focuses on both doing research and developing technologies. At the same time, the RTO must actively pursue the twin transition by putting forward digital and sustainable issues in its mission. TNO prioritizes this by putting forward societal challenges in its strategy, focusing on a sustainable and digital society. Furthermore, TNO is involved in researching and developing technologies at which TNO is concerned with how the innovations they develop land in society. The goal of TNO is to link people and information to produce ideas that will improve society's well-being and the industry's ability to compete sustainably (*Organisatie | TNO*, n.d.). Finally, the chosen case must provide the researcher with sufficient relevant information. This criterion is also fulfilled, as the researcher completed an internship of 6 months at TNO. This internship provides the researcher access to relevant information and the ability to collaborate with employees from TNO on projects in which the twin transition was managed. Because of this, an in-depth single case study was performed that used multiple methods for data collection.

4.2. DATA COLLECTION

This section describes the method of data collection in this research. Multiple data sources were employed following the case study approach, providing rich and nuanced insights and improving theory development from empirical and naturally occurring field data, which is also referred to as data triangulation (Farquhar et al., 2020; Ozcan et al., 2017; Yin, 2009). Triangulation of the data was used as follows; first primary data was collected through interviews and participant observation, complemented with secondary data to broaden the perspective and validate the emerging findings (Ozcan et al., 2017). Through triangulation of methods by drawing insights from rich primary and secondary data, the validity of the findings is claimed to be achieved (Eisenhardt, 1989; Yin, 2009).

4.2.1. PRIMARY DATA

The following section describes the two primary data types collected during this research. Semi-structured interviews and participant observation are part of the primary data during this research.

SEMI-STRUCTURED INTERVIEWS

Primary data was collected through qualitative semi-structured interviews with main informants from two different units from TNO. These are the Mobility & Built Environment unit and the ICT, Strategy & Policy unit (*Organisatie | TNO*, n.d.). These units make consistent contributions to the development of sustainable and digital societies, making them valuable sources of information regarding the twin transition.

A semi-structured interview was chosen as the primary data collection technique, as it allows participants to raise whatever issues they consider essential and because semi-structured interviews are appropriate for capturing new ideas that were brought up during the interview. Furthermore, semi-structured interviews allow the interviewer to probe any matters needing clarification and explore topics relevant to the researcher more deeply (Patton, 2002; Westby et al., 2003). A semi-structured interview is a method in which the interviewer introduces the topic and prepares it with a brief descriptive statement and an open lead-in question, which the interviewee then explores as they want. The key themes covered in the interviews were drawn from the transition management framework introduced in Chapter 3. A set of additional exploratory questions was prepared for each key theme, which can be found in the interview guide in Appendix. A. This interview guide was consistently used with every informant, which implies reliability of the research was achieved.

The formulation of the interview guide questions was facilitated by utilising the four operationalization tables in Chapter 3. The process of operationalization to interview questions is demonstrated with the help of an example. For example, the transition arena consists of several sub-themes, one of which is establishing the transition arena. To operationalize this concept, it is crucial to identify the role of RTOs in establishing a network comprising frontrunners with diverse competencies, interests, and backgrounds. Which leads to the following interview question: *To what extent are you aware of an existing network with multiple actors who work on sustainability issues in which digitalization is incorporated? Or digitalization issues in which sustainability is incorporated? And what is your role and/or the role of TNO in this network?* The questions from the interview guide were all managed to develop in this manner, with this procedure being followed for all the sub-themes of the four theoretical constructs.

In this case, purposeful and snowball sampling was used to identify the primary informants from the two different units from TNO. Purposeful sampling is a method for finding people with a vast knowledge of or experience with the phenomena of interest (Creswell & Clark, V. L. P, 2018). Snowball sampling involves asking each respondent for recommendations for other suitable informants (Brayda & Boyce, 2014). The researcher contacted individuals via direct email requests who operate between sustainability and digital issues within their unit regarding projects they work on or research they perform on these topics. After an interview was scheduled with a selected individual, they were asked if they could identify other individuals within TNO that operate between sustainability and digital issues. A total of 17 interviews were conducted with employees from TNO. A list of interviewees is present in Table 5. Two of the 17 interviews were conducted face-to-face, while 15 were conducted via Microsoft Teams. All interviews were conducted in Dutch and translated into English.

Table 5. Interviewees from the Dutch Research and Technology Organization TNO

Interviewee ID	Unit	Department
[I.I.1]	ICT, Strategy & Policy	Strategic Analysis & Policy
[I.I.2]	ICT, Strategy & Policy	Strategic Business Analysis
[I.I.3]	ICT, Strategy & Policy	Monitoring & Control Systems
[I.I.4a]	ICT, Strategy & Policy	Strategic Business Analysis
[I.I.4b]	ICT, Strategy & Policy	Strategic Business Analysis
[I.M.5]	Mobility & Built Environment	Buildings & Energy Systems
[I.M.6]	Mobility & Built Environment	Marketing & Sales
[I.M.7]	Mobility & Built Environment	Building Materials & Structures
[I.I.8a]	ICT, Strategy & Policy	Embedded Systems Innovation
[I.I.8b]	ICT, Strategy & Policy	Embedded Systems Innovation
[I.I.9]	ICT, Strategy & Policy	Strategic Business Analysis
[I.I.10]	ICT, Strategy & Policy	Networks
[I.I.11]	ICT, Strategy & Policy	Monitoring & Control Services
[I.M.12a]	Mobility & Built Environment	Market Buildings, Infra & Maritime
[I.M.12b]	Mobility & Built Environment	Digital Built Environment
[I.I.13]	ICT, Strategy & Policy	Data Ecosystems
[I.M.14]	Mobility & Built Environment	Digital Built Environment
[I.M.15]	Mobility & Built Environment	Climate, Air & Sustainability
[I.I.16]	ICT, Strategy & Policy	Technical Sciences-Networks
[I.M.17]	Mobility & Built Environment	Market Buildings, Infra & Maritime

WORKSHOP ORGANIZATION AND OBSERVATION

The primary data collection, through interviews, was complemented with a form of participant observation. As for now, this study utilized the TM framework mainly descriptively through conducting interviews. However, the TM serves two purposes: it can be utilized prescriptively, offering guidance for shaping policy processes, implementation, and evaluation, and it can be utilized descriptively, providing insights into the evolution of transitions (Stephens & Graham, 2010). The TM framework is also used prescriptively in this research by performing participant observation, including an action research element. Therefore, participant observation in this research is related to the other data collection techniques by employing an action research approach which provides additional valuable insights into the contribution of RTOs to the governance of the twin transition (Stephens & Graham, 2010).

Participant observation is a technique that enables researchers to learn about the behaviours of the population being studied in a natural environment by observing and taking part in those activities (Kawulich, 2005). Participant observation was performed as the researcher is performing an internship at the selected case and is, therefore, a group member being studied (Kawulich, 2005). Participant observation was conducted by organizing and observing a workshop focused on converging green and digital transitions. Whereas the workshop primarily emphasized the role of digital tools and technologies in enhancing sustainability.

The workshop, which was held on the 14th of April 2023, was conducted to develop a systematic and industrialized approach to enable large-scale circularization of bridges, leveraging enhanced digitalization. The workshop serves as a twin transition case, as both green and digital elements were combined, where digital tools are essential for achieving sustainability in enabling large-scale circularization of bridges. The workshop highlights the interdependency of green and digital aspects, demonstrating the necessity of digitalization in realizing sustainable outcomes in this context. To put this

in motion, the workshop was facilitated by an employee of TNO in collaboration with the researcher. Table 6 provides supplementary details regarding this employee’s specifications.

Table 6. The interviewee from the Dutch Research and Technology Organization TNO

Interviewee ID	Unit	Department	Function
[I.I.18]	ICT, Strategy & Policy	Strategic Business Analysis	Innovation Orchestrator

During the workshop, a collective of approximately 25 participants convened to delineate the trajectory of the transition towards a planned and industrialized infrastructure sector. The 25 individuals all represented different organisations seen as leaders in the industrialisation of the infrastructure sector, with a specific focus on bridges. These individuals include engineering firms, contractors with their own niche innovations that are not considered mainstream initiatives, and governments. Some start-ups are also participating, and the governments present serve as implementing governance rather than direct policymakers. Whereas policymakers are interpreted as the authorities that make policy. The workshop’s objective was to bring all leaders together to map out a collective trajectory towards a planned and industrialized infrastructure in which the increased use and development of digital technologies are required.

The researcher actively collaborated with the employee from TNO in organizing the workshop by engaging in formal discussions during the internship. The researcher provided guidance and suggestions to assist the TNO employee in workshop management preparation. In this context, the researcher established connections between the theoretical constructs, namely the transition arena, transition agenda, transition experiments, and transition evaluation and monitoring, with the substantive content addressed in the workshop. The researcher interpreted how these theoretical constructs could be meaningfully applied within the workshop, subsequently conveying this interpretation to the TNO employee. The TNO employee utilized this information in multiple ways: (1) to establish a theoretical foundation by linking the workshop to relevant theories, (2) to clarify TNO’s role within the workshop, and (3) to provide guidance on structuring the workshop effectively. Based on the information, the TNO employee conceived the idea of dividing the workshop into two parts. The first part would concentrate on the transition arena and establishing a vision, while the second part would centre around the transition agenda.

After completing the necessary preparations, the workshop was conducted on the 14th of April, 2023. During the workshop, the researcher assumed the role of a detached observer, documenting the participant’s actions and behaviours within their natural context, abstaining from direct interaction or engagement. Throughout the workshop, the researcher focused on the dynamic interplay between TNO and the various stakeholders present, aiming to foster the exchange of ideas and critically examine different viewpoints concerning the twin transition. As this study focuses on the contributing role of RTOs in the governance of the twin transition solely, the role of TNO during the workshop was given the most attention. Field notes were taken to ensure that observation is a valuable research method. Field notes, consisting of written observations recorded during or immediately following the participant observation in the field, serve as a significant resource for understanding the encountered phenomena by participants (Phillippi & Lauderdale, 2018). Field notes are a collection of documents from a researcher’s experience being observed in a particular place or area (Phillippi & Lauderdale, 2018). In this study, field notes were taken during the workshop to ensure the researcher remembered all valuable information.

The four theoretical constructs of the TM framework were used to structure the observation of the workshop. As the workshop concentrated on the transition arena and around the transition agenda, the researcher focused on the presence or absence of strategic and tactical activities performed by the TNO employee. Consequently, the researcher mainly focused on the role of TNO in the workshop and the interaction between TNO and other actors.

Following the workshop, a formal scheduled conversation occurred between the researcher and the employee to validate the findings from the workshop. In addition, one formal semi-structured interview was conducted to reflect on the role of TNO during the workshop and the roles identified from the other semi-structured interviews. Furthermore, the employee from TNO was asked about what other roles TNO could perform in such workshops or in general to push forward the twin transition. The interview guide for this formal semi-structured interview can be found in Appendix. B.

4.2.2. SECONDARY DATA

Throughout the study, the primary data was complemented by secondary data collection. Two types of secondary data were selected based on specific criteria. Firstly, the data is sourced exclusively from TNO, without any collaboration with other parties, as this research specifically focuses on the contribution role of RTOs. Secondly, the data provide insights into the current and future activities or goals of TNO, demonstrating the contribution of RTOs to various topics. The secondary data includes several roadmaps and a strategy document based on these criteria.

The secondary data includes four roadmaps, of which two roadmaps belong to the Mobility & Build Environment (MBE) unit, and two belong to the ICT, Strategy & Policy (ISP) unit. These roadmaps are relevant secondary data because they outline the technical and methodological knowledge being created, the effect TNO expects to achieve with this knowledge, and the variety of financing sources required for this effort. Through roadmaps collection, TNO manages its research's strategic programming. If both units within TNO prioritize the convergence of the green and digital transition and their role in this convergence, it would be documented in the roadmap, thereby providing valuable insights for analysis.

In addition to the four roadmaps, TNO's strategy document was also included. TNO's strategy document embeds the ambition of TNO to be at the forefront of the current developments to respond to the changing world and defines what is needed to achieve it. This strategy document considers the threats and opportunities of the digital transition while also focusing on the Green Deal, in which countries of Europa are showing that they want to tackle the climate and energy challenges together as a matter of urgency. This document provides valuable insights into the convergence of the green and digital transition and the role of TNO in this convergence. The documents mentioned above were explicitly chosen for their ability to shed light on the current situation and future direction of TNO in the context of the twin transition. In Appendix. C, a list of the analyzed documents and their specifications can be found.

4.3. DATA ANALYSIS

Data collection and analysis were carried out simultaneously until theoretical saturation was attained. After conducting an interview with a respondent from TNO, the interview was transcribed and subsequently shared with the informant to validate (Farquhar et al., 2020). For the transcription of the conducted interviews, a transcription tool, known as Amberscript was employed to ensure a professional

and accurate representation of the spoken interview. Hereafter, the transcripts were translated into English.

Subsequently, the interview transcripts were analysed using an abductive approach (Vila-Henninger et al., 2022). The software programme NVivo was used to manage, analyse and visualize the qualitative data and documents systematically and individually. First, a deductive approach was used, which involved creating a deductive codebook based on the characteristics and indicators of the four theoretical constructs. The deductive codebook can be found in Appendix. D, Table D1. In this deductive approach, the original words of the interviewee are connected to the pre-determined codes in the deductive codebook. This deductive codebook was extended through open coding, which allowed for creation of new categories that arose from the interview data besides the created codes of the four theoretical constructs (J. M. Corbin & Strauss, 1990). The first step of the open coding process involved allocating first level codes, where codes were ascribed closely to the original words of the interviewee. In the second step, second-order codes were generated by categorising the earlier described first-order codes into more interpretative second-order categories. Axial coding is a technique that was used for this to further refine and elaborate on the categories and themes that have been identified (J. M. Corbin & Strauss, 1990). The second-order codes were further grouped through top-level coding in step three. The final codebook can be found in Appendix. D, Table D2. An example of the coding process is provided in Table 7. After examining the interview transcripts, the analysis extended to the secondary data. This phase involved employing the same methodology as previously described.

Table 7. Example of the coding process

Top level	Second order	First order	Quote
Transition arena	Multi-stakeholder engagement and involvement	TNO has a combining role	“So we actually perform multiple roles in a network, sometimes or in many cases one orchestrates the network but other colleagues again bring in the content that should be discussed in the network.”
Twin transition	Challenges between green and digital	-	“Definitely yes there is a great challenge between green and digital topics, one is that we simply do not speak the same language. Yes that is something I recognize quite often, which is a great challenge.”

4.4. RESEARCH QUALITY

In this part of the research, the research’s quality is evaluated to determine if the procedures were executed accurately and supported by scientific justifications. The quality of the research depends on internal and external reliability and internal and external validity (Bryman, 2015).

Internal reliability depends on inter-observer consistency and often refers to whether the observations of different researchers are the same (Bryman, 2015). As one researcher carries out this study, it can be stated that internal reliability is achieved. External reliability accounts for the objectiveness and repeatability of the research (Bryman, 2015). This research provides a step-by-step methodology that can be replicated, ensuring external reliability. The reliability of the interviews is ensured through careful preparation and documentation, as interview guides were created in advance based on the theoretical framework, providing valuable insights and allowing for the replication of the interviews. External reliability

is also achieved by creating a deductive codebook with codes that align the concepts derived from the theoretical framework. This ensures the coding process remains consistent and reliable across different coders and interview transcripts. Moreover, this study employed multiple data sources, enabling data triangulation and enhancing the reliability of the findings. The triangulation of data sources adds strength to the study's findings and increases confidence in the reliability of the research outcomes.

Internal validity in qualitative refers to the extent to which the findings accurately represent experiences, perspectives or phenomena under investigation (Bryman, 2015). In this research, internal validity is achieved by ensuring that the study participants are relevant to the research question, as purposeful sampling is used. External validity refers to the generalizability of the findings to other contexts beyond the specific study (Bryman, 2015). The codebook is regularly reviewed and refined throughout the coding process to address any ambiguities or inconsistencies that may arise, allowing for the emergence of additional codes from the interviews. Therefore, the codebook incorporates the richness and complexity of the participants' perspectives, enhancing the findings' external validity. However, it is essential to note that the generalizability of the research is limited as this study encompasses one single case study and is, therefore, challenging to generalize (Bryman, 2015; Yin, 2009).

5. RESULTS

To answer the research question: “*How can Research and Technology Organizations (RTOs) contribute to the governance of the twin transition?*” The result section is divided into three different subsections. Section 5.1 describes the role of TNO as an intermediary within the nexus of digitalisation and sustainability. The second section, section 5.2, describes the role of TNO within the four different theoretical constructs of the TM framework, namely the transition arena, transition agenda, transition experiments, and transition evaluation and monitoring. The final section, section 5.3, describes a specific twin transition case in action in which the role of TNO is explained.

5.1. TNO AS TWIN TRANSITION INTERMEDIARY

This section explores the focus of sustainability, digitalisation and the interplay between sustainability and digitalization within TNO as an intermediary. By examining the different perspectives on digitalization and sustainability, this section aims to shed light on the integration and potential synergies and barriers between sustainability and digitalization in organizational contexts in which the role of TNO as an intermediary is emphasized.

5.1.1. PRIMARY FOCUS ON SUSTAINABILITY

Intermediaries, including RTOs like TNO, are positioned at the convergence of two distinct transitions: the digital transition and the sustainable transition (D.5) (D.1 is the document ID, see Appendix. C). This implies that both topics are considered relevant within the organisation. However, following the interviews, it becomes clear that the primary focus is still on sustainability as both the ICT, Strategy & Policy (ISP) and Mobility & Built Environment (MBE) units indicated that there is unequal importance to sustainability and digitalisation. As the two topics are seen as distinct challenges. Whereas, in general, sustainability takes precedence as the primary focus, digitalisation assumes a secondary role in the overall context (I.I.13; D.1; D.2) (I.I.13 is the interviewee ID, see Table 5). Within the two units, different perspectives exist on sustainability, where sustainability is seen as both an outcome and motive (I.I.13; D.1; D.2; D.3; D.4). Previously, sustainability did not receive constant significance over time, and it was primarily viewed as an economic consideration. However, it has gained more broad attention, and its importance has notably increased (I.M.6; I.M. 17; D.4). This shift can be attributed to investor preferences for future-proof investments and increased awareness of sustainability among customers. The MBE unit responded to this shift by developing tools to enhance transparency in sustainability, which in the construction sector led to an intensified focus on sustainably encompassing the broader sustainability transition (I.M.6).

The ISP unit encompasses multiple departments. Within these departments, varying attitudes toward sustainability are observed among TNO employees. Some departments lack the space for green ideas without a predefined roadmap, as sustainability is not always the primary driver for organizations and companies (I.I.3; I.I.8a; I8b; I.I.13: D.4). Instead, cost reduction typically motivates organizations and companies, with sustainability serving as a beneficial by-product (I.I.3; I.M.6: I8a; I.I.8b). This is recognized as one of the main challenges which can arise while focusing and integrating sustainability within TNO. One interviewee highlights the difficulty of generating profits solely from sustainability initiatives for companies, necessitating additional justifications for investments (I.I.8b). This interviewee states, “*Yes, what is difficult with sustainability is that it is not very easy to make money from it. So, I always kind of look for it as well. What is the reason for doing this apart from being sustainable? Because if you only do it for sustainability then it is just very difficult to get a company to invest in it.*”(I.I.8b).

5.1.2. DIGITALIZATION AS AN ENBLER FOR GREEN

As previously mentioned, TNO, as an intermediary, positions itself at the intersection of the two transitions. While sustainability remains the primary focus within TNO, there is increasing recognition of the significance of digitalization within both units (D.3; D.4; D.5). This acknowledgement arises from TNO's ability to establish stronger connections between sustainability and digitalization, perceiving the latter not as an independent objective but as a facilitator to achieving sustainability goals. Given the current sustainability transition, specific data-related work is necessary to support the sustainability transition and associated studies. Therefore, digitalization is perceived as a tool for addressing sustainability concerns (D.1 & D.2). As one interviewee stated, *"So digitalization can again be used to improve sustainability, and digitalization is of course also used to make things transparent, to set things up more efficient, where you can also work on sustainability. But we also use digitization to find solutions [...] so yes, actually digitalization is a kind of enabler that actually serves for everything."*(I.M.6). It is frequently emphasized that digitalization is employed as a radical and portent means to achieve sustainability improvements (I.I.1; I.I.2; I.M.6; I.M.12b; I.I.13; I.M.15; I.M.17). As one interviewee mentioned *"Most of the time, we are about climate change anyway we want something from that and then the hammer we have is IT. So we are trying to get that hammer to hit especially yes, say towards sustainability."*(I.I.13). However, there is an ongoing ambiguity regarding the purpose of digitalization as an independent proposition or its inherent connection to other broader objectives, a point of clarification sought by the interviewees in the MBE unit.

However, the opposite is true for the ICT department within the ISP unit. The interviews and roadmap show that sustainability is considered the secondary focus in this department as the focus lies primarily on digitalisation (D.3). One interviewee notes, *"I notice that I am now mainly concerned with purely the digitization issue and that the sustainability aspect is a kind of nice to have or what is it called an additional value? Often it is also the case that many companies are already quite sustainable."* (I.I.3). It is noteworthy that the interviewees active in the ICT department do not necessarily prioritize sustainability but are more concerned with managing the digital transition (I.I.8a & I.I.8b).

5.1.3. DIGITALIZATION AS A CHALLENGE FOR GREEN

Nevertheless, not all respondents explicitly acknowledge the vital link between digitalization and sustainability, although there are several areas where digitalization can enhance sustainability. This is because, in some cases, digitalization poses significant challenges for businesses (I.I.3; I.I.4a; I.I.4b; I.I.9; I.M.12a). Moreover, the magnitude of the digitalization aspect is often underestimated, and major digitalization initiatives are expected to require considerable effort (I.I.4b). Another challenge highlighted by the ICT department from the ISP unit is the fact that digitalization, in its way, gives rise to new possibilities that consume energy and therefore negatively contribute to sustainability (I.I.8a). Because numerous digitalization initiatives exhibit an inherent paradox concerning sustainability, as they tend to consume substantial quantities of energy (I.I.2). One interviewee mentioned, *"So we are now doing work on sustainability in digital.[...] people say around the 4 percent of the total global energy consumption is used in all ICT systems and everyone says that this will increase. [...] but if you want to contribute something to the climate you should also look at how you could make ICT more efficient?"*(I.I.16). However, according to several interviewees, these questions are not frequently asked despite their importance (I.M.15 & I.I.16). Another common issue is the lack of effective communication and mutual understanding between the ICT department and other departments within the units (I.I.2; I.I.3; I.M.12a; I.M.12b).

5.1.4. CONVERGENCE BETWEEN GREEN AND DIGITAL

Despite the emphasis placed on sustainability within the respective units and the recognition that digitalization is both an enabler and a challenge for the green transition, both units have begun actively incorporating digitalisation in their projects (D.5). A respondent mentioned that the integration of green and digital aspects is increasingly gaining momentum since multiple initiatives are emerging and finding fertile ground (I.I.10). The interconnection between digitalization and sustainability is increasingly being observed across various departments within the units as both transitions aim to achieve a shared objective (I.I.1; I.I.3; D.4). While each topic has traditionally received individual focus, there is now a convergence and closer integration between them (I.I.2 & D.4). This proximity was not always the case, as historically, the two subjects were not strongly linked within TNO, but they are progressively aligning (I.I.2 & I.I.3). As expressed by an interviewee, *“Over the past fifteen years, we have witnessed an increasing convergence of these two domains. A decade ago, we were already working on the topics of green ICT, as we recognized the growing impact of ICT on sustainability.”* (I.I.2).

However, it is noteworthy that this interweaving of green and digital concepts has not been prevalent within the ICT department for an extended period, indicating a positive shift in recent times (I.I.10; D.3). Moreover, at the same time, there exists a vision within TNO regarding the digitalization-sustainability nexus, translating this vision into tangible products presents a significant challenge (I.I.3; D.3; D.4).

5.2. THE ROLE OF TNO TOWARDS THE TWIN TRANSITION

This section explores and elaborates on the role of TNO in the transition management (TM) framework. Based on this, the contribution of RTOs to the governance of the twin transition is determined.

5.2.1. THE ROLE OF TNO IN FACILITATING A TRANSITION ARENA

The role of TNO in facilitating twin transition arenas is divided into three sub-themes: establishing transition arenas, developing a shared perspective on the transition through interaction within the arena, and finally articulating a common vision of the transition based on this shared perspective. Within each of these three sub-themes, the role of TNO is examined.

THE ESTABLISHMENT OF A TRANSITION ARENA

The transition arena exists of frontrunners, which are considered individuals with specific competencies and innovative ideas or practices about a determined problem which are considered vital for transition processes (D. Loorbach & Rotmans, 2010; D. Loorbach & Wijsman, 2013; Wittmayer et al., 2017). To create a balance group, these frontrunners are chosen using various methods, including in-depth interviews, substance and process criteria, and psychological testing (D. Loorbach & Rotmans, 2010). The transition arena is central and crucial in the transition management framework.

Several transition arenas are identified that explore the link between digitalization and sustainability within the ISP and MBE unit (I.I.1; I.I.10; I.M.12; I.M.14). While some of these transition arenas already have formal names, the majority of them are yet to be named, reflecting on the ongoing emergence of these arenas. The transition arena's formal establishment has yet to occur, although significant informal activities are already in progress. For instance, the participation of individuals in chat groups who actively strive to integrate green and digital aspects in various new projects and technologies (I.M.5). Chat groups can function as an initial stage in the establishment of a transition arena, providing a space in which participants can get to know each other and share each other's visions. However, these chat groups do not involve formal agreements or binding arrangements and cannot be seen as transition arenas. These informal networks can eventually become more formal and established transition arenas based on the

twin transition context. This process can be accelerated through political pressure coming from the EU Commission or the Dutch government (I.I.11). Examples of established transition arenas are the Sustainable Digital Infrastructure Alliance (SDIA), which is a collaborative effort towards achieving sustainable digital infrastructure by 2030 and the foundation Hortivation, which is a foundation that focuses on technical innovations and knowledge management in greenhouse design and construction industry. Hortivation furthers the development of digital cultivation with the help of big data and ICT. Both arenas incorporate green and digital topics as integral aspects of their daily operations. Several other formal twin transition arenas have been identified, which can be found in Appendix. E for reference. Between the different formal and informal transition arenas, a range of arenas operates at different levels, including both European and national levels. Additionally, these twin transition arenas exhibit varying degrees of organization. Some are highly structured, with frequent participant engagement and regular monthly meetings. In contrast, other networks have a more flexible and loose approach (I.I.11 & I.M.15).

Within TNO, the formation of arenas varies, with a majority of arenas emerging organically through TNO employees, leveraging their networks to identify and engage potential participants (I.I.1; I.I.10; I.M.12; I.M.14; I.M.15). This phenomenon occurs as a result of the connections and interactions among various stakeholders from previous projects. It is common for new ideas to emerge during the course of these projects, prompting the search for collaborative partners to pursue these new ideas jointly (I.I.2). Another approach to establishing such arenas is by actively bringing together diverse stakeholders who should collaborate in response to EU projects. TNO frequently employs this method to facilitate stakeholder collaboration (I.I.3; I.M.5; I.I.16).

TNO assumes various roles in establishing transition arenas in the twin transition context, outlined in Table 8. These roles can coexist and be fulfilled simultaneously, implying that engaging in one role does not preclude TNO from pursuing another. TNO can assume multiple roles concurrently depending on the context and objectives. The first identified role is the initiating role. In this role, TNO is involved in initiating and establishing consortia or arenas that bring together the intersecting themes of digitalization and sustainability (I.I.1; I.M.5; I.M.6; I.I.8a; I.I.10). This is done through connecting stakeholders from various backgrounds and sectors that could converge to address challenges related to the twin transition (I.I.12b & I.M.17). In addition to initiating arena formation on their own or with colleagues, TNO employees also engage in other roles depending on the context in which they find themselves.

Connecting stakeholders within green and digital themes, which is progressively increasing, is another critical role identified (I.I.1 & I.I.10). Within this role, TNO facilitates the collaboration of diverse stakeholders. The connecting role differs from the initiating role as TNO does not set up a network with different stakeholder. It connects stakeholders and stimulates interaction between them, so these stakeholders eventually see the value of creating a network by themselves. The focus of TNO in this role lies in finding relevant stakeholders, appreciating their potential contributions to the twin transition, and establishing their changes to connect them with other stakeholders. TNO seeks to foster a feeling of value and mutual benefit by actively bringing stakeholders together and encouraging engagement. This helps the stakeholders understand the importance of forming a network or creating a consortium to achieve common goals in which green and digital topics are converged. The connecting role TNO pursues adds significant value, especially during the start-up phase of arena formation. Bringing individuals from different ecosystems together is regarded as one of the most significant roles of TNO in advancing the twin transition (I.I.4a; I.I.4b; I.M.12b; I.I.16; I.M.17).

The final identified role in establishing twin transition arenas is the boosting role. In this role, TNO actively promotes and facilitates the participation of stakeholders in the arenas. Moreover, TNO plays a crucial role in driving the network by initiating specific projects or emphasizing essential topics within the network (I.I.2; I.I.10; I.M.14). In addition, it is typical for a consortium of stakeholders to evolve into a social organization where TNO employees often actively participate in the organization’s board. This involvement demonstrates TNO’s commitment and active engagement in the collaborative efforts and provides TNO with the opportunity to boost the arena in a particular direction (I.M.6; I.I.9; I.I.16).

Table 8. TNO’s roles in the establishment of twin transition arenas

Role TNO	Description	Quote
Initiating role	Assuming the initiative to establish arenas independently.	“Because we see all kinds of issues, we are often also one of the first to see what is going on in such a sector [...] which can lead to us taking the initiative to set up those kind of networks.”(I.M.17)
Connecting role	Facilitating the connection and interaction between stakeholders, fostering their recognition of the value of establishing an arena.	“We bring different stakeholders together and each has their own contribution in the networks, we encourage that.” (I.I.1)
Boosting role	Actively promoting and assisting to other stakeholders in their participation within the arena or boosting the arena itself.	“Within the domains where I have visibility, it is evident that TNO also plays a guiding and boosting role.” (I.I.1) “As TNO, we are active in the creation and governance of such a network.” (I.I.16)

INTERACTION AND COLLABORATIVE LEARNING WITHIN THE ARENA

Following the emergence of a transition arena, whether it is a formal established or informal loose arena, fostering interaction and facilitating joint learning is a critical aspect of the arena (D. Loorbach, 2010). TNO emphasizes the importance of facilitating knowledge exchange within an arena, recognizing it as a significant process. The interaction between various stakeholders involved in twin transition arenas is highly valued and occurs frequently (I.I.11; I.I.12a; I.M.17). The following quote supports this: “Yes, *there is a lot of contact here. Once you join in such a network, there is a lot of contact there.*” (I.M.17). Apart from fostering interaction between different individuals both units indicate that it is also significant to create sessions for pitching ideas and receiving constructive feedback on digital and green topics. Within these sessions, participants are encouraged to share their expertise, ideas, and experiences, which are considered essential for the arena and its direction towards the twin transition (I.I.1; I.I.13; I.I.16). However, the frequent and intensive interaction among stakeholders is not always seen as advantageous. It is often recognized that developing a comprehensive plan or vision can be highly inefficient due to extensive interaction among the involved parties (I.I.11). TNO assumes various roles throughout these activities, outlined in Table 9.

The first identified role is the arranging role. In this role, TNO is involved in organising workshops focusing on sustainability and digital topics. Within such workshops, interaction and collaborative learning occur among the different stakeholders. The organisation of workshops encompasses various aspects, including

the logistical arrangements of the workshop, facilitating the discussions, evaluating the outcomes, and the subsequent planning of follow-up workshops. For example, in the transition arena smart industry TNO was involved in setting up workshops. Smart industry contributes to the twin transition by significantly contributing to sustainability goals by implementing advanced technologies, automation, and digitalization in industrial processes. Therefore, smart industry can improve efficiency, optimize resources, and reduce negative environmental impacts. The second identified role of TNO in the interaction and collaborative learning within transition arenas among the different stakeholders is the providing knowledge role. This involves facilitating the introduction of topic-specific expert knowledge, providing stakeholders with new information on unfamiliar topics, and ensuring a shared knowledge base within the arena. This knowledge exchange process is considered crucial for the arenas' progress in the context of the twin transition, as it promotes equal understanding and expertise among all participants on specific subjects. It is significant to mention that besides this more basic knowledge, an arena operates effectively when all stakeholders possess specific and detailed knowledge from which other stakeholders can learn.

Table 9. TNO's roles in interaction and collaborative learning in transition arenas

Role TNO	Description	Quote
Arranging role	The organisation of workshops in which interaction and collaborative learning is a central part.	"Indeed, it is common for TNO to take initiative in organizing and facilitating such sessions and workshops." (I.M.6)
Providing knowledge role	Facilitating the alignment of knowledge held by various stakeholders through exchanging knowledge.	"[...] of course, we also have an important substantive role in the knowledge we provide to such a network of different players." (I.I.1)

THE DEVELOPMENT OF A SHARED VISION

After the establishment of a transition arena and the subsequent interaction and collaborative learning among stakeholders within it, the emergence of a shared twin transition vision is expected. According to theory, shared visions develop through interaction and discussions between stakeholders active in the transition arena (D. Loorbach, 2010). Contrary to theoretical expectations, the process of generating a shared vision within the TNO context differs in some cases. Since in most cases, the shared twin transition vision is not generated through interaction within the arena but serves as the initial foundation for bringing individuals together. This implies that the vision is already there or there is already an idea about the vision before the different individuals connect to a twin transition arena. This phenomenon can be attributed to specific instances where the project initiator, whether it is TNO or another project leader, presents the vision and expects other stakeholders to align with it, consequently fostering their engagement and connection to the arena (I.I.10 & I.I.13). Based on the interviews, the shared visions related to the twin transition primarily emphasize the integration of green aspects into digital issues and vice versa despite the specific context of the arena, as there are for example, the Dutch Green Building Council (DGBC) and BioDT. Whereas BioDT focuses on helping, protecting and restoring biodiversity, and the DGBC is a networking organization for sustainable construction and real estate. Specifically, within the ICT department of the ISP unit, integrating green elements into digital development is seen as a crucial aspect of shaping a shared vision. In contrast, other departments prioritize integrating digital aspects into green issues to expedite achieving sustainability goals.

Occasionally, a vision may emerge from conversations between officials and different parties, sometimes involving TNO. Meaning that TNO is not necessarily directly involved in formulating a vision (I.I.13). If TNO is involved in the development of a shared twin transition vision, it mainly arises due to internal discussion with colleagues and other stakeholders. During these discussions, information is exchanged, which leads to creating a vision based on the convergence of green and digital. This process is considered dynamic, and a significant aspect here is the diversity in the interaction between employees from TNO with various other parties to create a complete picture of the phenomenon and eventually come up with a shared vision. This vision is formulated by TNO based on the diverse information they have collected and analyzed (I.I.13). Therefore, TNO assumes two roles within the development of a shared vision, the presenting role and the guidance role, which are outlined in Table 10.

Consequently, the creation of a vision in which the twin transition is present is perceived differently within TNO. In some cases, the creation of a vision is not always guaranteed. It depends on the project lead of the group or network (I.M.17). In other cases, a shared vision is considered the starting point for putting together such a network. However, there are instances where multiple parties within an arena seek guidance from TNO regarding the vision and direction they should pursue (I.I.13). Consequently, it can be inferred that the vision creation process is not linear or uniform but rather multifaceted, with various approaches employed. There is no single prescribed path for vision formation, as it varies across different contexts, leading to diverse and distinct approaches.

Table 10. TNO's roles in the development of a shared twin transition vision

Role TNO	Description	Quote
Presenting role	TNO presents a vision and hopes other stakeholders will align with this vision and connect to the network.	“Yes we do start with a shared vision otherwise no people will join.” (I.I.1)
Guidance role	TNO provides advice on the direction or vision a network should move into as this is asked.	“We are often asked through different project leaders, what should our vision be?” (I.I.3)

Based on the interviews, several suggestions were provided by the interviewees to enhance and improve the fulfilment of TNO’s roles in facilitating the transition arena within the twin transition context. Several interviewees indicated that further emphasis should be placed on business development to put forward projects in which the twin transition is present. To do so, TNO should strive to be a unifying factor within the regions of the Netherlands which can be improved by focusing on business development, according to interviewee I.I.2. Additionally, several interviewees indicate that it would be advantageous for TNO to present increased solutions incorporating digital and green topics that align with the established vision, as this will generate increased attention towards TNO and the twin transition (I.I.2; I.I.13; I.M.17). Consequently, TNO can be given a more prominent position in various contexts and thus participate in more meaningful discussions (I.I.13). Finally, one interviewee indicates that it would be easier if the management of TNO explicitly directed her employees to address digital and green issues together. This would facilitate the employees’ work, as it is essential to remember that TNO is an organization that needs to sustain projects and demonstrate value to the outside world. More than working on topics that employees find highly motivating is required (I.I.9).

5.2.2. THE ROLE OF TNO IN DEVELOPING A TRANSITION AGENDA

The role of TNO in developing a transition agenda is divided into two sub-themes: creating a shared agenda and establishing activities, projects, or instruments to pursue the transition agenda. Within each of these two sub-themes, the role of TNO is examined.

CREATION OF A SHARED AGENDA

From theory, a transition agenda is created based on the shared visions and the shared problem perception derived from the transition arena. A transition agenda is a coordinated action plan for initiating or furthering transitions and forms the compass that transition arena participants can follow during their transition journey (D. Loorbach & Rotmans, 2006). Within TNO, a familiar and widely used tool is used to create a shared agenda which is referred to as a roadmap or research agenda (I.I.1; I.M.5; I.M.6; I.I.13). It is significant to note that such roadmaps or research agendas are not static documents; they undergo continuous refinement and adaption to align with evolving arena changes (I.I.13). The development of a roadmap in which the twin transition is present is predominantly viewed as a collective effort that involves the active participation of all arena participants. Due to this, the effectiveness of roadmaps can vary significantly. Within the established BioDT transition arena, in which the twin transition is central as it responds to crucial EU and international policy initiatives, including the EU Green Deal and UN Sustainable Development goals while using data in conjunction with digital infrastructure, predictive modelling, and AI solutions, the development of a roadmap or agenda is perceived challenging due to the extensive scope of the BioDT transition arena. As this poses challenges in achieving a comprehensive mutual understanding among participants, thereby requiring significant time and effort (I.I.9). Despite the presence of well-organized roadmaps or research agenda, it is significant to mention that in some cases, these roadmaps do not necessarily guarantee clarity or coordination actions among the involved parties (I.I.4a & I.I.4b).

A twin transition roadmap functions differently for all participants. As for some interviewees, a roadmap functions as a guiding vision, outlining the arena's desired future state. It provides a structured plan with step-by-step actions that need to be undertaken to increase the convergence of green and digital aspects (I.I.5). To accomplish each step, different partners are sought within and beyond the arena. As one interviewee mentioned, *"[...] and then you have a kind of plan, in which you have to go through steps to get there. [...] we should do this and that fits into such a [...] and then you start looking for partners for that."* (I.M.5). A roadmap serves as a strategic function and improves operational network coordination. As it may be utilized to establish meeting schedules, set deadlines, and define feedback mechanisms among the participating parties (I.I.10). This process may differ across arenas, for example, in more mature arenas such as the Dutch Green Building Council, which are often professionally organised, the establishment of a roadmap is done in a highly programmatic way (I.M.17). This, however, requires much effort and is mainly done when an arena exists of a programme council.

Moreover, there are instances where the absence of the creation of a roadmap or plan in which the twin transition is present can be observed. This is attributed to the fact that green and digital topics are often already integrated within different organizations as individual themes they wish to address, thereby eliminating the need for a reliable roadmap (I.I.13). In other cases, the roadmap was already created before the arena around it was established, at which the emergence of an arena and the projects within it is the cause of the predefined roadmap or agenda (I.I.13). Examples of such arenas include the smart industry and 3GPP arenas, which initially began with an established agenda or roadmap and subsequently sought additional partners for participation (I.I.1 & I.I.10).

TNO assumes several roles in creating a shared agenda towards increasing convergence of green and digital topics, outlined in Table 11. The first identified role is the contributing role. As TNO plays a significant role in actively contributing to the establishment of a roadmap, leveraging its extensive experience in this area (I.I.2 & I.M.6). TNO is aware of the rules of the game and therefore able to offer a significant contribution to the development of twin transition roadmaps (I.I.2). The second identified role is the observing role as TNO plays a prominent role by engaging with a diverse range of actors and stakeholders within and beyond the arena. This extensive interaction enables TNO to observe the evolving dynamics and requirements of various actors concerning the twin transition, consequently facilitating the development of a roadmap that accommodates their diverse needs (I.M.5 & I.M.7). The third identified role is the interconnecting role. As TNO plays a role in interconnecting different initiatives and ideas from various stakeholders to ensure all individual visions are considered (I.I.1). Which ties the fact that TNO is constantly looking one step ahead to make sure all relevant parties are onboard (I.I.2).

Table 11. TNO's roles in creating a shared agenda in the twin transition context.

Role TNO	Description	Quote
Contributing role	TNO plays a role in contributing to the development of a roadmap.	“What you see is that we as TNO are involved in roadmap development, so we develop a planning for both for example in the region such as [...] but also on European level.” (I.I.1)
Observing role	By actively engaging with diverse actors and stakeholders within and outside the network, TNO observes valuable insights into various dynamics, which can then be used to develop a roadmap.	“In how I experienced it, is that it very much comes from TNO, from listening carefully to what is going on. I think that we, as TNO, are one of the few players who have the overview.” (I.M.17)
Interconnecting role	Through interconnecting initiatives and ideas from various stakeholders, TNO ensures that all individual visions are considered while developing a roadmap.	“And we also make sure that that is interconnected with each other also with the aim because ultimately, if you really want that chain to be effectively digitised and if you really want to be able to deploy these kinds of transitions well yes then you also want to expand your network more and more.” (I.I.3)

ESTABLISHING PROJECs, ACTIVITIES, OR INSTRUMENTS TO PURSUE THE TRANSITION

Following theoretical perspectives, addressing the challenges delineated in the transition agenda requires the assurance of adequate resources for the implementation of proposed strategies. Consequently, it becomes crucial to determine the roles and responsibilities of various actors involved in developing or implementing specific activities, projects, or instruments (D. Loorbach & Rotmans, 2006). However, the role of TNO in establishing activities, projects or instruments for the green and digital transition is not delineated, as the process of assigning roles and responsibilities to specific actors is primarily organic. It is observed that individuals tend to engage in areas they are already involved in, aligning their roles with their existing expertise and interests (I.I.1; I.I.2; I.I.4a; I.I.4b I.M.5; I.I.13).

TNO undertakes a specific role in implementing projects, activities, or instruments to advance the twin transition. This role is delineated in Table 12 and referred to as the establishing role. As TNO takes on a role to ensure that digital and green topics fall within the project determined. This can be determined as TNO is involved in the engagement of multiple stakeholders, which means TNO is reaching out to them to determine the areas, which can be both green and digital, in which they are already actively involved and those in which they still need to engage (I.M.6). TNO can do so as it has the ability and freedom to look from different perspectives to the projects and the content of the projects (I.M.6). This role is essential to make sure the twin transition is put forward as most stakeholders involved tend to adopt a narrow viewpoint primarily centred on their interests and perspectives (I.M.7). This is the case because every stakeholder is mainly occupied with their activities in their specific field of expertise, especially when many different stakeholders are participating in the network (I.M.7; I.I.9).

Table 12. TNO's role in the establishment of projects, activities, or instruments to pursue the twin transition.

Role TNO	Description	Quote
Establishing role	TNO identifies and establishes pertinent topics, ensuring their alignment with the projects.	“To identify the right topics, you have to have many conversations in the market, so you can observe what different markets needs and see where changes in the market arise. But it is also a combination of expert perspectives from TNO that have a desired direction to address market gaps and challenges in order to contribute to a better world.” (I.M.5)

Based on the interviews, several suggestions were provided by the interviewees to enhance and improve the fulfilment of TNO’s roles in developing a transition agenda in the context of the twin transition. Numerous interviewees express the need for additional time and resources to enhance further the development of research agendas or roadmaps (I.I.1; I.I.2; I.I.13; I.M.14; I.M.17). Moreover, sustaining enthusiasm and motivation among individuals involved in agenda-setting is of utmost significance according to interviewee I.M.14. Finally, initiating non-binding table conversations with diverse stakeholders in specific domains can also be beneficial as these bring forward dialogues that can enhance the agenda development process (I.I.13).

5.2.3. THE ROLE OF TNO IN PARTICIPATING IN TRANSITION EXPERIMENTS

The role of TNO in participating in transition experiments in which green and digital topics are converged is divided into two sub-themes: the creation and implementation of transition experiments and the evaluation and investigation of uncertainties coming from transition experiments. Within each of these two sub-themes, the role of TNO is examined.

THE CREATION AND IMPLEMENTATION OF TRANSITION EXPERIMENTS

According to theoretical perspectives, transition experiments and activities are implemented at the operational level of transition management. These initiatives aim to further develop, broaden, and amplify existing and planned actions and initiatives (D. Loorbach, 2010). Transition experiments often develop in the form of field labs, pilots or use cases (I.I.1; I.I.2; I.M.7). Field labs encompass specific applications within a project, which facilitate collaboration among a consortium of stakeholders focused on a specific topic or area of interest (I.I.2). In the context of BioDT, various distinct use cases have been identified, each representing a unique scenario where different parties collaborate, either collectively or independently. These use cases collectively contribute to the overarching vision of the arena, allowing the complex

problem to be deconstructed into manageable components for more efficient and effective work (I.I.9). In the context of the twin transition, numerous field labs, pilots, and use cases are commonly developed, serving as experimental initiatives that contribute to the convergence of sustainability and digitalization. However, although these experiments' specific names and details are not explicitly mentioned during the interviews, their existence and significance are acknowledged.

The extent to which these field labs or pilots contribute to the twin transition varies among the interviewees, as some state that a field lab or pilot arises when the different parties see it as a relevant topic or theme within the research. Digitalisation and sustainability are not a starting point for this pilot. However, it would happen when including aspects of the two becomes interesting. On the other hand, the two topics can sometimes be really intertwined within the pilot or field lab. As one interviewee states, “So then you actually create an opportunity from which both an ICT and a sustainability perspective development can take place.” (I.I.2). Great differences can arise concerning the focus of the twin transition, which depends on the project context.

Table 13. TNO's roles in the creation and implementation of transition experiments

Role TNO	Description	Quote
Facilitating role	Facilitating the field labs.	“Yes, we as TNO often facilitate such a field lab.” (I.I.10)
Proactive role	TNO anticipates the future steps of the field labs.	“[...] I notice that we are often one or two steps ahead of what is actually the majority of such a pilot.” (I.I.2)
Motivating role	Getting all different stakeholders on board in such field labs.	“Yes, that to me is always a very logical role that TNO has. So we see something that is becoming more and more important we set up a project and start looking for parties that should get onboard.” (I.I.12a)
Gap analysis role	Addressing gaps and shortcomings within the projects.	“Initially, various individual projects emerge. [...] Throughout this process, certain elements within the projects may be refined or removed, while new elements may be introduced.” (I.M.17)

TNO assumes several roles in creating and implementing transition experiments contributing to the twin transition, outlined in Table 13. The first role is facilitating, as TNO sometimes facilitates field labs in the twin transition context. However, not all field labs are facilitated by TNO only, as most of them are also designed in collaboration with other parties, including TNO (I.I.11; I.I.12a; I.I.12b; I.M.15). The second role is the proactive role as TNO exhibits a proactive approach by anticipating on future steps in the twin transition process, rather than focusing on the success of the pilot. The third role is motivating, as TNO is occupied with getting everybody on board and providing them with the right level of knowledge within pilots, field labs, or use cases (I.I.11). Finally, the gap analysis role is the fourth identified role of TNO. TNO can engage in diverse activities while developing field labs, fulfilling a significant role in addressing existing gaps and shortcomings (I.I.11).

EVALUATION OF UNCERTAINTIES

According to theory, several types of structural uncertainties may hamper transition processes. To identify and differentiate between structural uncertainties and uncertainties that can be reduced, it is essential to keep a range of possibilities open and explore the nature of these uncertainties within transition experiments (D. Loorbach & Rotmans, 2006). Uncertainties regarding the convergence of sustainability and digitalization arise from a diverse range of different things. There is a great variety in what is the cause of uncertainties and how TNO deals with these. One interviewee indicated that fast-moving legislation could lead to uncertainties concerning the twin transition, as it is challenging to keep track of the changing legislative landscape (I.I.11). Another uncertainty is the uncertainty of the project's outcome. It is always a surprise where a project is going, and it is challenging to predict the outcome (I.I.11 & I.I.16). Another uncertainty arises from the gap between specialist-intensive knowledge and more broad knowledge.

Consequently, the diverse array of stakeholders needs help understanding each other which can impede effective communication and create barriers (I.I.2 & I.M.14). A fourth barrier was identified as some interviewees mentioned that most stakeholders are too occupied with their business as usual, through which not enough time is available to focus on the development of field labs or pilots (I.I.3; I.M.14). Another uncertainty is the process of funding, it can sometimes be challenging to find funding for projects especially when the projects are more broadly connecting other projects according to an interviewee (I.M.17). An additional factor where uncertainties concerning the twin transition can arise from, is the inherent difficulty in determining which parts of the process will be done individually or collaboratively. In certain instances, working alone may yield quicker results. However, working collaboratively on certain aspects can contribute to more remarkable progress (I.M.6). The last identified source of uncertainty relates to the interpersonal dimension. When an individual departs from an organization, it can introduce new uncertainties as a new person must be found within the organization and build new relationships. This may result in the fact that a project needs to commence from the beginning (I.I.4a; I.I.4b; I.I.9). Nonetheless, it is noteworthy that such occurrences are not always negative as new individuals can also infuse the project with fresh ideas and visions regarding the twin transition context (I.I.9). The uncertainties mentioned above can manifest during transition experiments focused on the twin transition. However, the interviewees suggest that these uncertainties are not exclusive to such experiments. Similar uncertainties may arise in entirely different context-related experiments as well.

TNO assumes several roles in dealing with the uncertainties mentioned above, which are outlined in Table 14. The first role is the clarifying role. In this role, TNO makes the uncertainties as comprehensible as possible (I.M.7 & I.I.11). The second role is initiating. In this role, TNO is occupied with setting up public and private initiatives, which can sometimes also result in more funding which eventually reduces uncertainty in terms of funding (I.I.1). The third role is the providing knowledge role. In this role, TNO stimulates a network by providing knowledge and elaborating on this with the various stakeholders involved in projects or experiments (I.I.3).

Table 14. TNO's roles in evaluating uncertainties.

Role TNO	Description	Quote
Clarifying role	TNO assumes the responsibility of enhancing the comprehensibility of uncertainties.	“Yes, so our aim is to understand and assess the uncertainties, risks, benefits and costs. In order to get a full understanding of these different factors and make decisions based on them.” (I.M.7)
Initiating role	TNO assumes the responsibility of setting up public and private initiatives.	“So if you start scaling up new innovations, it sometimes requires an extra impulse or an extra subsidy to take that last step, so that you can develop just that little bit more. We set up these kinds of public-private initiatives for that purpose.” (I.I.1)
Providing knowledge role	Facilitating the alignment of knowledge held by various stakeholders through exchanging knowledge.	“In some cases yes we do teach new things within such a network, to make sure that everybody is on the same page.” (I.I.9)

Based on the interviews, several suggestions were provided by the interviewees to enhance and improve the fulfilment of TNO’s roles in participating in transition experiments in the context of the twin transition. One of these is the understanding of each other’s dynamics, as this facilitates a deeper understanding of each other’s perspectives within the twin transition arena (I.I.3; I.I.4a; I.I.4b; I.M.14). In some cases, arenas or networks bring together highly specialized experts who strive for precision alongside management personnel who are comfortable navigating certain levels of uncertainty (I.M.14). Recognizing and embracing these differences is considered essential for expediting the progress of twin transition-related experiments according to interviewee I.M.14.

5.2.4. THE ROLE OF TNO IN MONITORING AND EVALUATING THE TRANSITION

MONITORING DEVELOPMENTS

Continuous monitoring plays a crucial role in the search and learning processes of a transition (D. Loorbach & Rotmans, 2006). It involves the monitoring of the four different elements, namely the transition arena, transition agenda, transition experiments, and transition evaluation, to identify areas that require improvement or adjustment (D. Loorbach, 2010; D. Loorbach & Rotmans, 2006). There is a wide range of monitoring and evaluation-based diversity within TNO. Based on the interview findings, the act of monitoring is primarily carried out within the context of transition experiments focused on converging sustainability and digitalization, serving the purpose of evaluating the success or failure of these twin transition experiments (I.I.1; I.M.6; I.M.7; I.I.1; I.I.13). To determine this, the roadmaps are consulted as a tool to determine whether the project is moving in the right direction. As one interviewee mentioned, “*We will monitor this, we have created a roadmap and every few months we assess where we are in relation to this roadmap. Are we on track? Are we succeeding our goals? In order to determine whether what we are doing makes sense, we keep track of a lot of things, including our time and financial investments.*” (I.I.13). Additionally, progress reports are used in some twin transition experiments, which in some cases are strict requirements (I.I.11). Progress reports are periodically produced to let the various stakeholders know how the project is going and what progress has been achieved in the context of the twin transition. Another tool to keep track of the progress within experiments is using key performance indicators (KPIs). TNO

commonly employs these KPIs to formally track project progress and communicate achievements to stakeholders external to the project group (I.I.11). Furthermore, a steering committee or project leader may occasionally be utilized to monitor or take initiative within the project (I.I.2).

As a result, the monitoring and evaluation process towards the twin transition often leads to modifications in the content of a project (I.M.6). These modifications are based on the insights and feedback gathered through monitoring activities, allowing for adjustments to be made to improve the project’s effectiveness or address any identified shortcomings (I.I.1; I.I.2; I.M.6; I.I.11). The perception of how modifications are made within a project varies among the interviewees, while some interviewees indicate that the lessons learned are implemented naturally throughout the experiments, others highlight that the process of implementing these lessons can be slow and challenging (I.I.1; I.I.2; I.M.6). On the contrary, several interviewees mention that monitoring and evaluation still happens too little (I.I.2; I.I.3; I.I.4a; I.I.4b; I.M.17). As one interviewee states, *“So we are what I say, we are good at making plans and setting goals as a network, but we are not so good at going back and asking, where are we? And what did we accomplish?”* (I.M.17). Some respondents even claim that they have not seen monitoring in particular situations, however they are nevertheless aware of its importance and advantages (I.I.2 & I.I.3). According to the interviewees, there is little emphasis on monitoring in relation to the other theoretical constructs such as the transition arena and transition agenda. Their primary focus is on monitoring experiments, if monitoring is conducted at all.

Based on the interviewees’ responses, it can be inferred that TNO’s role is primarily limited to monitoring experiments and their progress. Therefore, TNO assumes only one role in monitoring the transition developments, and this role is outlined in Table 15. This role is the monitoring role of project progress based on the twin transition context, as TNO occasionally performs the task of project monitoring. However, if TNO does so, it cannot maintain an executive position within the project as it is perceived as unfair to supervise your own work. Furthermore, it is stated that TNO does not perform the task of monitoring on its own as it sometimes works together with other parties.

Table 15. TNO's role in monitoring developments in the twin transition context

Role TNO	Description	Quote
Monitoring role	TNO monitors the progress of the experiments.	<i>“[...] we are also asked to monitor certain projects and innovation programmes. There are often programmes where we do not have an executive role as well, since you cannot wear two hats at once.”</i> (I.I.1)

Based on the interviews, several suggestions were provided by the interviewees to enhance and improve the fulfilment of TNO’s roles in monitoring the twin transition process. The current perception within TNO is that monitoring in the twin transition context is not given adequate attention or priority as a dedicated role (I.I.4a; I.I.4b; I.M.6; I.I.9; I.M.14). Several interviewees indicate that more time and attention to these monitoring activities is necessary (I.I.4a; I.I.4b; I.M.6; I.I.9; I.M.14). However, interviewee I.M.14 states that the current restrictions on the financial resources allowed for monitoring provide a severe obstacle.

5.3. SPECIFIC CASE IN ACTION: THE INDUSTRIALISATION WORKSHOP

This section elaborates in-depth explanation of a specific twin transition case in action and the role of TNO in this case. This case provides additional valuable insights into the contribution of RTOs to the governance of the twin transition by employing an action research approach. The case discussed in this section is situated within the context of the twin transition, as its objective is to establish a systematic and industrialized approach that relies on advanced digitalization to facilitate the large-scale circularization of bridges. The case is discussed following the four theoretical constructs of the TM framework, namely the transition arena, transition agenda, transition experiments and transition monitoring and evaluation.

5.3.1. ESTABLISHMENT OF A TRANSITION ARENA

To establish the larger transition towards a planned and industrial infrastructure sector, North Holland municipality has set up an innovation programme to facilitate large-scale circularization of bridges that relies on advanced digitalization. The initial scope of this innovation programme is regional, intending to expand its reach to a national level subsequently. This innovation programme exemplifies the twin transition, which involves the interconnection of sustainable and digital transitions. In this context, circularization is linked to sustainability goals, and digitalization is considered a prerequisite for achieving these large-scale circularization efforts. The innovation programme aims to incentivize stakeholders in this specific domain to contribute to this larger transition via subsidies and funding. The transition arena comprises established stakeholders in various domains, including engineering firms, contractors, governmental organizations, a selection of start-ups and, finally, TNO who are actively engaged in the transition process. According to the interviewee, the established participants in this context are regarded as frontrunners due to their development of technologies that facilitate the large-scale circularization of bridges. These technological advancements set them apart from other players in the infrastructure sector and positioned them at the forefront of large-scale circularization of bridges.

A few scheduled meetings were organised to facilitate the active engagement of these stakeholders in the broader transition towards a planned and industrial infrastructure sector. Of which the second meeting took place on April 14th, 2023, as a workshop was initiated to get everyone on the same page regarding the transition (I.I.18). The transition arena fostered an inclusive environment where the different stakeholders felt comfortable expressing their perspectives and seeking clarification (field notes, April 14, 2023). This open atmosphere encourages active engagement and facilitates a meaningful knowledge exchange among the diverse actors. Moreover, the primary objective of this workshop was to provide comprehensive insights into the motivations driving the participating stakeholders, clarify their respective roles and responsibilities, outline the trajectory of the innovation programme, and shed light on the specific requirements necessary for its establishment. This in-depth understanding aimed to foster effective program development, enabling meaningful contributions towards the intended transition. The workshop served as a platform for information gathering and knowledge sharing to inspire stakeholders and provide insights into future endeavours aimed at a planned and industrialized infrastructure sector. Through creating a shared understanding and garnering support among the involved parties, the workshop aimed to ensure alignment and continued engagement, reinforcing the notion that the pursued actions are meaningful and beneficial for all different stakeholders involved (I.I.18).

TNO pursued different roles within the context of the transition arena. TNO's role in the preparation for the workshop encompasses two distinct types of preparation. First, the preparatory phase involves assessing the workshop's necessity and establishing its purpose. Second, there is the logistical aspect of organizing the workshop itself, which includes designing the workshop structure, developing the necessary

templates, and creating an environment conducive to active participation, meaningful contributions, and facilitating the conversation from the participants (I.I.18). The interviewee performed the role of innovation orchestrator, which is considered a role that has significant value because due to its role as an innovation orchestrator, TNO possesses the capability to establish networks such as the one in question (D.5). In the context of workshop preparation, TNO has assumed the role of orchestrator, facilitating the mobilization and engagement of individuals, encouraging collaborative thinking, and fostering support for the innovation program (I.I.18). TNO has gained significant knowledge and expertise on how to take on such an orchestrator role and what kind of different methods or working forms could be applied to set up a workshop like this eventually. However, according to the interviewee, enhancing the content and execution of the workshop could be achieved by allocating additional resources. This could lead to the involvement of active participation of additional TNO employees, assuming roles as both orchestrators and content experts, facilitating more profound discussions and fostering a coherent workshop (I.I.18). Moreover, the interviewee acknowledged the valuable contribution of the researcher in the preparation of the workshop. Specifically, the researcher aided in identifying various concepts, such as the notion of a transition arena.

Additionally, the interviewee highlighted the researcher's assistance in shaping the workshop's content by aligning it with established theory. At which the TM framework provided valuable insights for the interviewee in terms of organizing and scheduling the workshop. Furthermore, the role of the interviewee became further elucidated through informal discussions with the researcher (I.I.18).

5.3.2. DEVELOPMENT OF THE TRANSITION AGENDA

During the workshop, a collaborative exchange of visions occurred among the stakeholders, ultimately formulating four distinct visions. In this process, the TNO employee played a crucial role in facilitating and guiding the participants through this visioning process (I.I.18). These four visions described each a different plan to facilitate the large-scale circularization of bridges that relies on advanced digitalization. However, the convergence of these four visions did not result in the formation of a unified shared vision in which all the present stakeholders engaged and collaborated (I.I.18). The allocated timeframe during the workshop proved to be inadequate for the successful formation of a shared vision, which had been the intended objective (field notes, April 14, 2023). Because of this, a transition agenda in which actionable steps should be identified and refined for the realization of a planned and industrialized infrastructure sector could not be created. From this workshop, it follows that it is essential to realize that the comprehensive process, encompassing the transition from individual visions to collective visions and action planning, cannot be effectively captured within a single workshop or a single session thereof (I.I.18). Therefore, a dedicated meeting was arranged, involving a select group of stakeholders from the transition arena.

From this meeting, an emergent narrative materialized, representing a shared vision that encapsulated the collective aspirations and goals of the participants. This vision includes standardizing and industrializing modules and applying industrial principles. Adopting a broader perspective requires implementing chain solutions supported by a robust IT infrastructure. Using cutting-edge digital techniques enables data traceability related to objects, elements, and materials, opening opportunities for enhanced automation. Eventually, to accomplish this shared vision, a comprehensive plan encompassing various action steps spanning from June 2023 to September 2023 was established, which is described as the transition agenda (I.I.18). This transition agenda represents a consolidated content plan that encompasses a diverse array of niche innovations and provides an elucidation of their integration within the context of industrialization and digitalization (I.I.18). Based on the aforementioned consolidated agenda, a series of activities will be

undertaken. These activities include conducting a comprehensive gap analysis, identifying key development themes, and assessing the feasibility and prioritization of these themes. This assessment will determine the necessary first steps to initiate the transition. Subsequently, project proposals will be drafted with the stakeholders involved, followed by concept development. The ultimate goal of this concept development is to facilitate the successful implementation of the identified initiatives (I.I.18).

The role of TNO in the development of the transition agenda is again facilitating the conversation between the different stakeholders and eventually having conversations with the different stakeholders individually in order to keep everyone on board and make sure they know what to do and what to expect (I.I.18). TNO's potential to fulfil this role more effectively could have been enhanced with increased resource availability, particularly in terms of financial support. This could enable the engagement of additional TNO employees, thereby accelerating the progress of this transition process in which a transition agenda was established (I.I.18).

5.3.3. TRANSITION EXPERIMENTS AND MONITORING AND EVALUATION OF TRANSITIONS

Living labs are initiated based on the transition agenda, which consists of written proposals. Living labs are projects or isolated experiments in which knowledge is implemented and developed (I.I.18). Participation is facilitated through a living lab, which serves as a programmatic learning environment in which partners interact in experimental settings to validate industrial applications on a larger scale. This interaction facilitates parties to improve and broaden their individual concepts as a result of inspiration (I.I.18). Therefore, the concept of living labs evolves around the consortium partners' involvement. Specific instances of living labs cannot be specified at this stage as they have yet to be materialized. TNO furnishes the various stakeholders with pertinent information regarding their expected contributions and maintains an open dialogue throughout the process (I.I.18).

Regarding monitoring and evaluation, minimal progress was observed during the meetings with TNO and other stakeholders. However, there were moments of reflection and discussion on the accomplishments and actions taken. These occurred during the interactions between the TNO employee and the researcher, which were deemed insightful according to the interviewee (I.I.18). Nonetheless, the interviewee emphasizes the significance of monitoring the outcomes of the experiments conducted in the living labs once they commence. However, since the experiments have yet to commence, the monitoring processes are not currently occurring.

The main takeaways from this twin transition case in action are that this workshop describes the establishment of a transition arena aimed at achieving a planned and industrial infrastructure, in which digitalisation is seen as an enabler and, therefore, contributes to the twin transition. This workshop aimed to align the stakeholders' perspectives and clarify their roles in this transition. TNO played the role of an innovation orchestrator and prepared for the workshop by assessing its necessity and organising its logistics. Four visions were formulated during the workshop, but a unified shared vision could not be achieved due to time constraints. A dedicated meeting was arranged to eventually create this shared vision and establish a transition agenda encompassing action steps to accomplish the shared vision. TNO performed the role of facilitating and connecting the stakeholders to make this happen. Eventually, living labs based on the transition agenda were planned as projects for implementing and developing knowledge. The abovementioned process and developments could have been enhanced with increased resources.

6. CONCLUSION

Intermediary actors play a pivotal role in expediting and facilitating transitions, by which research and technology organizations (RTOs), a specific intermediary actor, are notably recognized as a significant component of a nation's innovation system. Therefore, it is suggested that RTOs have a significant and influential role in the governance of the twin transition. However, there is a noticeable gap in the existing literature regarding this specific topic. This research fills this gap by finding the contributing role of RTOs in the governance of the twin transition. The theoretical and methodological approaches proposed in this research helped to investigate the role of RTOs. This research used the transition management framework to provide insights into the governance of intermediary actors in sustainability transitions. The methodological approach involves conducting a qualitative single case study at a Dutch RTO, the Netherlands Organisation for Applied Scientific Research, TNO. The methodological approach consisted of conducting 18 interviews with TNO employees, participating and observing a specific twin transition case in action, and investigating roadmaps and strategy documents of TNO. Therefore, the research answered the research question: How can Research and Technology Organizations (RTOs) contribute to the governance of the twin transition?

The case studied in this research is an example of a case in which the interconnection between digitalization and sustainability is increasingly recognized. However, despite this recognition, sustainability remains the primary focus, whereas digitalization is often seen as a means to achieve sustainability goals. Nonetheless, this particular case also reveals several challenges associated with the convergence of green and digital transitions, with the primary concern being the energy consumption resulting from digitalization, which negatively impacts sustainability.

RTOs contribute to the governance of the twin transition by engaging in strategic, tactical, operational, and reflexive governance activities. These activities do respectively occur in the transition arena, transition agenda, transition experiments, and monitoring and evaluation transition theoretical constructs. RTOs undertake multiple roles when examining each activity, as illustrated in Figure 4.

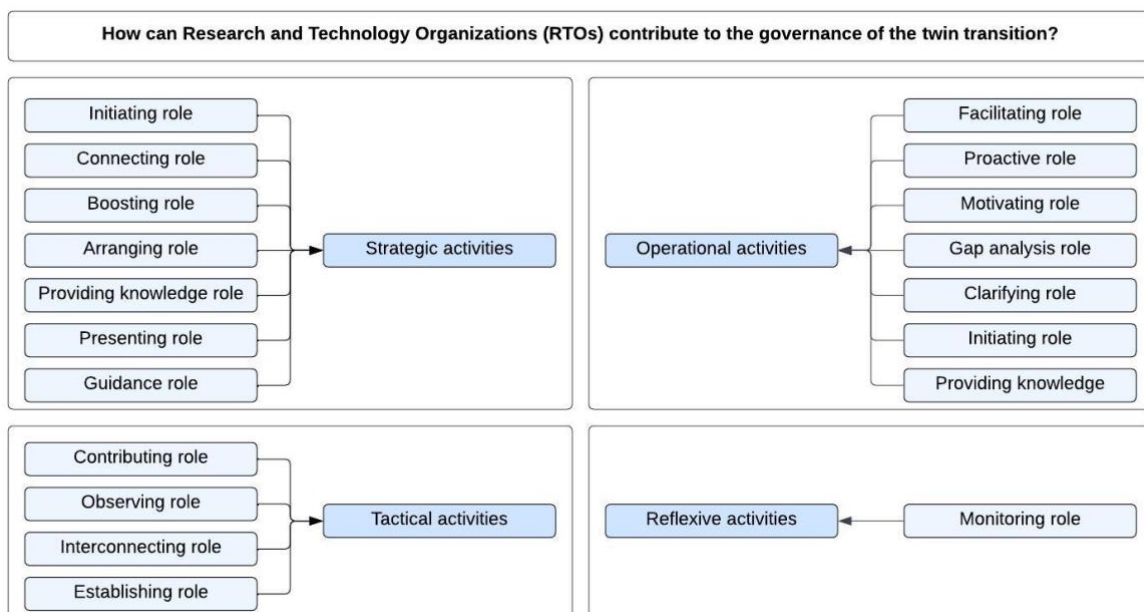


Figure 4. Roles of RTOs in the governance of the twin transition

Multiple arenas focus on the intersection of digitalization and sustainability, some already established while others are still emerging. The establishment within the twin transition context happens mostly organically at which RTOs perform the initiating, connecting and boosting roles. Stakeholder interaction within these twin transition arenas is frequent, posing challenges in terms of efficiency. RTOs facilitate this interaction by taking on the roles of arranging and providing knowledge. Developing a shared vision of the twin transition within the arena may or may not arise solely from interaction, as it can also serve as a foundational starting point. RTOs contribute to the process by presenting and providing guidance, although the creation of a vision is not guaranteed. Overall, RTOs perform diverse and significant responsibilities in the transition arena, promoting collaboration and shaping shared objectives regarding the convergence of green and digital.

Creating a shared agenda within the transition arena refers to developing a research agenda or roadmap, which involves active participation and collaboration among the participants. However, the presence of a roadmap may vary, and its function can serve as either a guiding vision or a strategic tool. RTOs play various roles in this process, including contributing, observing, and interconnecting. The assignment of roles and responsibilities to specific actors is primarily organic. Therefore, specific roles are undertaken elsewhere. However, RTOs undertake the establishing role by implementing projects, activities, or instruments to advance the twin transition, integrating green and digital topics within these initiatives.

Transition experiments play an essential role in the twin transition as they are valuable for exploring the convergence of sustainability and digitalization. Experiments are created and implemented through field labs, pilots, and use cases in which RTOs perform various roles, including facilitating, proactive engagement, motivating, and conducting gap analysis. Uncertainties arise during these experiments, such as fast-moving legislation, outcome uncertainty, knowledge gaps, stakeholder communication challenges, time constraints, funding issues and determining individual or collective responsibilities. RTOs play a significant role in addressing uncertainties by clarifying them, initiating actions, and sharing knowledge.

Furthermore, monitoring and evaluation are essential components of the transition process. However, monitoring mainly focuses on transition experiments rather than other transition elements. This process involves utilizing roadmaps and progress reports to assess project direction. The frequency of monitoring and evaluation can vary, with instances of inadequate attention. The monitoring process often leads to project modifications, although the speed and challenges of these modifications differ. RTOs perform a monitoring role in monitoring and evaluating transition experiments within the context of the twin transition and their progress.

To conclude, RTOs play an influential role in contributing to the governance of the twin transition by actively engaging in the roles depicted in Figure 4, which align with the activities associated with the four theoretical constructs of the TM framework.

7. DISCUSSION

Following the conclusion of the research, the discussion section is presented. This section is divided into three sub-sections. First, the scientific implications of the research are discussed. Second, the policy implications are discussed, and finally, the limitations of the research are presented.

7.1. SCIENTIFIC IMPLICATIONS

This research investigated the twin transition context from an intermediary perspective to understand the governance and roles intermediaries, and especially RTOs, perform in this context. Little research has been conducted on the role of intermediaries in the twin transition. However, considerable research has been conducted on the role of intermediaries in facilitating innovation processes and sustainability transitions (Kant & Kanda, 2019). From this, it follows that intermediaries are influential players in transitions who speed up the innovation process, encourage innovation, and assist transitions and sustainable entrepreneurship by playing a variety of roles (Gliedt et al., 2018; Kivimaa et al., 2019; Mignon & Kanda, 2018). These various roles of intermediaries are grouped into three functions: facilitating, configuration, and brokering. Facilitating means allowing other individuals the time and space to act. Configuration means altering the material and symbolic form of technology, often in subtle ways as well as how it is interpreted and used, and finally, brokering means establishing, nurturing, adjusting and altering connections between different actors (Stewart & Hyysalo, 2008). Consequently, existing literature primarily focuses on the role of intermediaries in transitions. However, there is a notable gap in examining intermediaries, especially RTOs, and their role in the twin transition. However, RTOs are believed to be influential actors in sustainability transitions as they are recognized as vital within a nation's innovation system (García-Vega & Vicente-Chirivella, 2020; Hargreaves et al., 2013; Intarakumnerd & Goto, 2018; Kang, 2021; Mignon & Kanda, 2018). A dedicated investigation into the roles and contributions of intermediaries to the twin transition is necessary. This research addresses this gap in the literature by investigating the twin transition context from an intermediary perspective by identifying the diverse roles performed by RTOs in the context of the twin transition. These roles are initiating, connecting, boosting, arranging, providing knowledge, presenting, guiding, contributing, observing, interconnecting, establishing, facilitating, being proactive, motivating, gap analysing, clarifying, and monitoring. According to Kant & Kanda (2019) and Stewart & Hyysalo (2008), most of these roles align with the functions traditionally attributed to intermediaries. However, according to the research RTOs also fulfil unique roles that were not yet identified as roles intermediaries perform. These unique roles are the boosting, motivating, clarifying, and monitoring roles which RTOs perform in the governance of the twin transition. The scientific implication of this research lies in identifying these roles and addressing the gap in the literature.

Furthermore, the European Commission introduced the concept of twin transition, positioning it as a part of the EU vision, which led to the development of policies in Europe and the Netherlands that aim to accelerate the twin transition. Several policies emphasize the increased focus on digital applications and their utilization for achieving sustainability goals (RLI, 2021). However, there is a need for more systematic consideration of how digitalization can be effectively guided to facilitate the twin transition towards a sustainable society. This research identified the contribution roles of RTOs to the governance of the twin transition. Therefore, the scientific contribution of this research lies in the twin transition phenomenon and how it should be governed.

The scientific implications of this research are limited in terms of theoretical contribution as this research is an example of a case in which the TM framework is applied. However, the TM framework is applied in a

slightly different context as it is used descriptively in this research and operationalized to one specific actor, namely RTOs. In most existing literature, the TM framework is used prescriptively, whereas a descriptive use of the TM framework is rather limited (Kemp et al., 2007; Kern & Howlett, 2009; Kern & Smith, 2008; D. Loorbach & Rotmans, 2010; Stephens & Graham, 2010). However, the utilization of the TM framework in this research follows common practices and therefore provides limited theoretical contribution.

This research makes a valuable contribution to the existing literature on the twin transition, which entails the convergence of both the green and digital transitions. It is recognized that achieving a well-balanced and harmonious twin transition involves equal consideration and representation of both transitions (István, 2020; Rehman et al., 2023). However, current literature suggests an imbalance between the two transitions, with digitalization often perceived as an accelerator or enabler for achieving sustainability goals (Del Río Castro et al., 2021; Lichtenthaler, 2021; Sareen & Haarstad, 2021; Stuermer et al., 2017). This research shows that RTOs follow a similar perspective, where sustainability is seen as the primary objective, and digitalization is a means to achieve this goal. This could be attributed to the early stage of development of the twin transition, indicating that the process will evolve over time and become more balanced. To explore this further, a longitudinal study could be conducted to track the progress of the twin transition within TNO and examine whether this imbalance changes over an extended period. Another way to explore if the research is conducted too early in the process of the twin transition is to investigate organizations, such as start-ups, that have successfully achieved a balance twin transition in their organization and learn from them.

7.2. POLICY IMPLICATIONS

The policy implications arising from this research provide insights into actionable steps that RTOs can undertake to enhance their contribution to the governance of the twin transition. This section outlines the key policy considerations derived from the research findings, presenting them as a comprehensive guideline in which several action steps are defined for each theoretical construct. This guideline is derived from the findings reported in each last paragraph of the following subsections, 5.2.1., 5.2.2., 5.2.3., and 5.2.4, wherein suggested recommendations of the interviewees are presented. These findings were consequently interpreted in the recommendations illustrated in Table 16.

Table 16. Guideline based on the findings of the research.

Theoretical construct	Policy implications
Transition arena	<p>By giving additional emphasis on business development, RTOs can contribute as a unifying factor in greening and digitalising the region.</p> <p>RTOs can put more effort into presenting enhanced solutions incorporating both green and digital topics.</p> <p>The management of RTOs can explicitly direct her employees to address green and digital issues.</p>
Transition agenda	<p>The allocation of additional time and resources for RTOs.</p> <p>Focus on sustaining enthusiasm and motivation among the individuals involved in agenda-setting.</p>

	RTOs can start by initiating more non-binding table conversations with diverse stakeholders.
Transition experiments	RTOs need to foster an understanding of each other’s dynamics, be mindful of contrasting approaches between ICT departments and other departments, and develop effective strategies to manage and reconcile them.
Transition monitoring	The allocation of additional time and attention to monitoring activities for RTOs. The allocation of adequate financial resources for RTOs.

7.3. LIMITATIONS OF THE RESEARCH

This single qualitative case study offers valuable insights into the contributing role of RTOs in the governance of the twin transition, with a specific focus on the case of TNO. However, it is essential to acknowledge that this research design limits the considerations of other actors involved in the governance of the twin transition, which is perceived as a limitation of the study. Due to choosing the current research design, a complete overview of all the different activities that could take place in the governance of the twin transition is lacking as this research solely focused on one of these actors, namely RTOs. The research addresses this limitation through an in-depth case study approach, allowing for detailed and extensive data collection. This in-depth analysis enables a nuanced understanding of the complexities of the studied case, providing valuable insights that may not be attainable through a broader and more generalized study. This limitation highlights the need for future research to explore the contributions of other actors in managing the twin transition. Investigating the roles and interactions of various stakeholders would provide a more comprehensive understanding of the governance dynamics in the twin transition and further enrich the body of knowledge in this field.

Moreover, another limitation of this study is that it presents a limited viewpoint on the role of RTOs in the governance of the twin transition, focusing solely on RTOs’ perspectives. Consequently, the roles other actors may perceive as crucial for RTOs to fulfil could differ, which is not considered in this research. This limitation is addressed in the research by including multiple perspectives on the role of RTOs by conducting interviews with various employees from TNO. Therefore, this study accounts for diverse viewpoints and recognizes the different perspectives on the roles of RTOs in the twin transition. However, this limitation highlights the need for future research in examining the perspectives of other actors regarding the crucial roles that RTOs should undertake to effectively contribute to the twin transition’s governance. Further investigation in this area is needed to understand the diverse perspectives on the roles of RTOs comprehensively through interviewing other actors involved in the governance of the twin transition.

Furthermore, as mentioned before, this research is based on a single qualitative case study, focusing on the contributing role of one specific RTO in the governance of the twin transition. However, an acknowledged constraint of single case studies is their limited generalizability, as findings from a single case study are challenging to generalize (Gomm et al., 2000; Yin, 2009). To improve generalizability, this study uses a theoretical framework to direct case selection, data collection and analysis (Gomm et al., 2000; Yin, 2009). Furthermore, this research incorporates multiple data sources for triangulation, enhancing the findings’ generalizability (Bryman, 2015; Yin, 2009). Even so, the generalizability remains limited. To mitigate this limitation, future research could employ a multiple case study approach,

investigating a range of diverse RTOs across the Netherlands or Europe. This would provide a deeper understanding of the roles played by RTOs in governing the twin transition.

Overall, this research focuses on a case that highlights the increased interconnection between digitalization and sustainability, emphasizing the role of digitalization in achieving sustainability goals. Despite the study's limitations, the research makes significant scientific contributions in examining the twin transition phenomenon, at which the role of RTOs in dual transitions is a novel insight into literature. Moreover, this study offers practical implications for RTOs in managing the twin transition within their organizations, guided by the four theoretical constructs of the TM framework. These implications provide actionable insights for RTOs to effectively govern the integration of converging green and digital aspects in their operations.

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APPENDIX. A

INTERVIEW GUIDE 1

Introduction:

Good morning/afternoon and thank you again for your time and effort in helping me with my research. Before we start the interview, I would like to tell you a bit more about myself and my background. Last year I started the research master's Innovation Sciences, before this master's I did the bachelor's in natural sciences and innovation management, both at Utrecht University. I am currently working on my master's thesis in which I am doing an internship at TNO. In this research I will investigate the twin transition and how this transition evolves, whereby the twin transition is the transition in which the digital and sustainability transition come together and at the intersection of these two transitions reinforce each other. I study the twin transition from a transition management approach which prescribes how such a transition can be actively stimulated through different actors. In my research I study the role of TNO, as an RTO, in this transition.

In order to conduct my research in the best possible way, I asked you to fill in the informed consent form I emailed you a couple of days ago. In this informed consent form it is stated that there will be a full anonymous handling which means that everything you say will be confidential. I will also ask you if it is okay if I record this interview in order to ensure that no valuable information will be lost. Do you agree with this, if yes I will start recording now.

Opening questions:

- To what extent are the issues 'sustainability' and 'digitalization' incorporated with each other in the projects/activities of the specific domain you work in?

Transition arena:

- To what extent are you aware of an existing network with frontrunners that are trying to challenge or change how things are towards more incorporation of the digital-green transition?
 - o What is the role of TNO in this network?
 - o What would enable you to (increase/improve) this role?
- How do these frontrunner actors interact and share ideas on the combination of digitalization and sustainability issues?
 - o What is the role of TNO in this interaction?
 - o What would enable you to (increase/improve) this interaction?
- To what extent is there a common vision focused on the incorporation of digital-green issues in this network of actors?
 - o What does this vision entail?
 - o What is the role of TNO in the development of this vision?
 - o What would enable you to (increase/improve) TNO's role in the development of a vision?

Transition agenda:

- To what extent is there a concrete plan or roadmap to implement this vision?
 - o What is the role of TNO in the development of such a concrete plan or roadmap?
 - o What would enable you to (increase/improve) in the development of such a concrete plan or roadmap?

Transition experiments:

- To what extent are you aware of the existence of projects that have a lot of potential in realizing this green-digital transition?
 - o What is the role of TNO in these projects?
 - o What would enable you to (increase/improve) the role of TNO in these experiments?

- What are typical uncertainties that arise from these projects and how are they dealt with?
 - o What is the role of TNO in dealing with these uncertainties?
 - o What would enable you to (increase/improve) the role in dealing with these uncertainties.

Transition monitoring and evaluation:

- How is progress monitored in the area of the green-digital transition in terms of visions, concrete plans or roadmaps, and projects?
 - o What is the role of TNO in monitoring this progress?
 - o What would enable you to (increase/improving) participating in the process of monitoring?
- How does TNO learn from monitoring this progress?

Closing:

We are nearing the end of the interview and I was wondering if there are any issues, which we did not discuss during our conversation, but which you find relevant and interesting to mention that relate to both sustainability and digitalisation issues? And I was wondering if you have any questions for me?

APPENDIX. B

INTERVIEW GUIDE 2

Introduction:

Good morning/afternoon and thank you again for your time and effort in helping me with my research. During this interview we will discuss your role during the workshop we both attended the 14th of April, I will ask questions in which you have to reflect on this role but also on other roles TNO pursues.

In order to conduct my research in the best possible way, I asked you to fill in the informed consent form I emailed you a couple of days ago. In this informed consent form it is stated that there will be a full anonymous handling which means that everything you say will be confidential. I will also ask you if it is okay if I record this interview in order to ensure that no valuable information will be lost. Do you agree with this, if yes I will start recording now.

Opening question:

- What was the role of this workshop within the twin transition?

Reflection:

- Could you reflect on the role of TNO in the preparation of the workshop?
 - o To what extent do you feel that the role you performed was sufficient to ensure smooth operation?
 - o What other roles could have contributed to the effective preparation of the workshop?
- Could you reflect on the role of TNO in managing the workshop?
 - o To what extent do you feel that the role you performed was sufficient to ensure smooth operation?
 - o What other roles could have contributed to the managing the workshop?
- Could you reflect on the role of TNO in facilitating the conversation among the other stakeholders within the workshop?
 - o To what extent do you feel that the role you performed was sufficient to ensure smooth operation?
 - o What other roles could have contributed to facilitating the conversation within the workshop?
- Could you reflect on the role of TNO in creating a shared vision during the workshop?
 - o To what extent do you feel that the role you performed was sufficient to ensure smooth operation?
 - o What other roles could have contributed to the creation of this shared vision during the workshop?
- Could you reflect on the role of TNO in creating a planning after the workshop took place?
 - o To what extent do you feel that the role you performed was sufficient to ensure smooth operation?
 - o What other roles could have contributed to creating a planning after the workshop?

Generic:

- What are things you would have done differently regarding the preparation, during and after the workshop?

- To what extent do you see the role you played within the preparation, during and after the workshop occur within TNO with regard to the twin transition?

What could TNO do in the future:

- What are examples of other roles that we did not discuss would be relevant for TNO to perform in preparation, during, or after the workshop?
 - o What are examples of other roles that we did not discuss that would be relevant for TNO to perform in projects in which the twin transition is prominent?

APPENDIX. C

SECONDARY DOCUMENTS

Table C1. Overview of secondary documents

Document ID	Type of document	Unit	Title	Number of slides
[D.1]	Roadmap	MBE unit	Roadmap buildings & infrastructure	10
[D.2]	Roadmap	MBE unit	Roadmap maritime & offshore	13
[D.3]	Roadmap	ISP unit	Roadmap ICT	8
[D.4]	Roadmap	ISP unit	Roadmap transitions & transformations	18
[D.5]	Strategy document	-	TNO strategy 2022 – 2025	104

APPENDIX. D
CODEBOOKS

Table D1. Deductive codebook

Top level	Second order
Transition arena	Multi-stakeholder engagement and involvement
	Co-creation of knowledge and solutions
	Collaborative learning
	Establishment of sustainability visions
	Enabling the role of TNO within the transition arena
Transition agenda	Prioritization of sustainability visions
	Setting goals and objectives
	Developing action plans
	Implementation of strategies and actions
	Resource allocation and mobilization
	Coordinating stakeholders
	Enabling the role of TNO within the transition agenda
Transition experiments	Multi-stakeholder engagement in the creation of experiments
	Identification of potential transition experiments
	Implementation of transition experiments
	Contribution experiments to sustainability visions
	Evaluation of uncertainties
	Enabling the role of TNO within transition experiments
Transition monitoring and evaluation	Feedback and learning mechanisms
	Continuous monitoring and evaluation
	Evaluation of the results of experiments
	Adaptability of the projects, initiatives, network
	Enabling the role of TNO within transition monitoring and evaluation

Table D2. Final codebook

Top level	Second order	First order
Digitalisation	Digitalisation as challenge	
	Digitalisation as enabler or purpose	
	Digitalisation is unnecessary	
	Little attention to digitalisation	
	Making digitalisation more green	
	Pure focus on digitalisation	
	Seeking the value of digitalisation for green	
	Strengths of digitalisation	
Sustainability	Challenges of sustainability	
	Increasing attention for sustainability	
	Little attention for sustainability	
	Sustainability as side effect	
	Sustainability as the goal	
Twin transition	Challenges between green and digital	
	Enable twin transition in TNO	
	Twin transition gains more attention	
	Intertwined	

	Not intertwined		
Transition arena	Absence of a network		
	Co-creation of knowledge and solutions		
	Collaborative learning	TNO organising workshops	
		TNO provides knowledge	
	Enabling the role within the transition arena		
	Establishment of sustainability vision		
	Multi-stakeholder engagement and involvement		TNO adjusts regulations
			TNO combines roles
			TNO has a connecting role
			TNO has a consultancy role
			TNO does research
			TNO drives/boosts
			TNO enables
			TNO facilitates
		TNO follows	
		TNO initiates	
	TNO integrates		
	TNO analyses trends		
	TNO transfers knowledge		
Transition agenda	Coordinating stakeholders		
	Developing action plans	TNO adheres to the vision	
		TNO is occupied with next steps in the project	
		TNO connects multiple action plans	
		TNO creates the agenda	
		TNO is involved in the creation of action plans	
	Enabling the role of TNO within the transition agenda		
	Implementation of strategies and actions		
	Lack of developing action plans		
	Resource allocation and mobilization		
Setting goals and objectives	TNO determines performance		
	TNO pursues green ambitions		
Transition experiments	Contribution experiments to sustainability visions		
	Development of potential transition experiments	TNO anticipates on experiments	
		TNO has a connecting role	
		TNO creates projects	
		TNO does all sorts of things	
		TNO has a facilitating role	
		TNO creates knowledge	
	Enabling the role of TNO within transition experiments		
	Evaluation of uncertainties		TNO makes uncertainties comprehensible
			TNO sets up public and private initiatives
		TNO stimulates networks	

	Identification of potential transition experiments	
	Implementation of transition experiments	
	Multi-stakeholder engagement in the creation of experiments	
Transition monitoring and evaluation	Adaptability of the projects, initiatives and network	
	Collaboration in continuous monitoring and evaluation	
	Continuous monitoring and evaluation	TNO monitors projects
	Enabling the role of TNO within transition monitoring and evaluation	
	Evaluation of the results of experiments	
	Feedback and learning mechanisms	TNO keeps the teams together
	Lack of monitoring	

APPENDIX. E

DETAILS ON TRANSITION ARENA

Table E1. Specific details on the transition arena

ISP unit	MBE unit	Interviewee ID
Sustainable Digital Infrastructure Alliance (SDIA)		[I.M.16]
Smart Industry		[I.I.1]
Biodiversity Digital Twinning (BioDT)		[I.I.9]
3GPP		[I.I.10]
	Dutch Green Building Council	[I.M.12a]; [I.M.12b]; [I.M.17]
	Learning environment circular viaducts	[I.M.14]
	Foundation Hortivation	[I.I.6]