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Mitigating uncertainties that affect the maturation of innovations in the infrastructure industry

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Abstract

Rijkswaterstaat (RWS) is the implementing governmental organization of the Ministry of Infrastructure and Water Management. RWS has set ambitious goals for the future, for which innovations are needed to obtain them. For this reason, RWS is concerned with the innovations that are developed in the industry. This research is about RWS' innovation processes, which currently do not give the desired innovation outcomes. Uncertainties that are inherent to innovation, obstruct the maturation of innovations as people are generally risk and uncertainty averse. The innovation processes at RWS are therefore analyzed from an uncertainty management perspective.

Six main categories of uncertainty that could affect the maturation of innovations are defined. Uncertainty can be related to the technology, the market, management, socio political factors, regulations, and time. There are seven types of public innovation policy that RWS can implement to mitigate these uncertainties. Systemic policies, regulatory policies, public procurement for innovation and support of private demand are policies known for affecting the demand for innovations. R&D subsidies, support of universities and public research, and pilot and demonstration plants are know the affect the supply of innovations.

There are multiple uncertainty mitigating procedures in place at RWS. Innovators can benefit from certain of these procedures depending on the situation the innovation is created in. There are two general procedures that are in place regardless of the situation. First, GPO technical experts can evaluate an innovation to assess if it complies with current regulations and are authorized to set requirements to comply with in order to comply. In this way regulatory uncertainty is mitigated. Second, are the teams that are concerned with determining what RWS's future needs will be, mitigating market uncertainty. Examples are the RWS Expedition 2050 team, the different goal teams, their road-map developers, and the Innovation Agenda team.

An analysis of interviews and observations has led to the construction of 18 needs that are related to the experienced uncertainties. These 18 needs serve as the requirements for the solution that is proposed. Due to the variety of these 18 needs, no single solution could be provided and a mix of seven solutions is proposed. These solutions together form the policy mix that RWS should implement. The different policies are structured in an idea to launch system based on the chronological order that the innovator will benefit from them. First, an innovation intermediary will be the link between the innovator and the different RWS processes. Second, procedures for regulatory qualifications are installed. Third, pilots and demonstrations should be coordinated. Fourth, public procurement for innovation should be used to actually start buying the innovations that contribute to the set goals. Alongside these policies it is recommended to implement stakeholder and change management to assure that the organization is ready to actually implement these innovations. The final important aspect of this idea to launch system is that every time before recourses are committed to an innovation in the form of any of these policies, a review committee assess the innovation on different criteria, such as the contribution to goals.

Key words: Innovation Policy, Uncertainty Mitigation, Infrastructure Industry, Idea to Launch Innovation Process, Innovation Maturation.

Management Summary

Rijkswaterstaat (RWS) is the implementing governmental organization of the Ministry of Infrastructure and Water Management. RWS provides a safe, livable, and accessible Netherlands. RWS is an organization that has set ambitious goals for the future, that are not achievable with incumbent technologies. Innovation in the road infrastructure industry is a topic of interest for RWS because they need these innovations to achieve the set goals. This research is about RWS' innovation processes, which currently do not give the desired outcomes. This thesis was set out to solve the following problem statement:

RWS needs innovations to create a safer, more sustainable, and better connected Netherlands. However, innovations in the industry do often not scale-up and commercialize as known and trusted incumbent technologies are often preferred.

In order to arrive at a solution for this problem statement, the following research question is formulated:

How can RWS mitigate uncertainties inherent to innovations in the infrastructure industry?

First, different uncertainties that affect the maturation of innovations can be defined. The first sub question therefore is*: What are the main uncertainties that affect the upscaling and commercialization of innovations?* There are 6 main categories that each have a number of subcategories that are relevant to innovations in the RWS context.

1. Technological
    - 1.1. Functioning
    - 1.2. Development
    - 1.3. Use
2. Market
    - 2.1. Customer Needs
3. Management
    - 3.1. Management Activities
    - 3.2. Metrics to Support Decision Making
    - 3.3. Business Model
4. Social/Political
    - 4.1. Diverse Interest
    - 4.2. External Communication
5. Regulatory
    - 5.1. Rule Content
    - 5.2. Final Compliance
    - 5.3. Qualification Method
6. Time
    - 6.1. Temporal Complexity
    - 6.2. Interconnectedness of Time
    - 6.3. Lead Times
    - 6.4. Timing

The second sub question is*: What is the role that public organizations like RWS and their public policy can play in overcoming uncertainties?* The uncertainties that are affecting innovation can be mitigated by public innovation policy, an overview is created of the potential tools RWS can use to

mitigate uncertainties. These policies can either affect the demand or the supply of innovations and are categorized based on that.

1. Demand Side Innovation Policy
    1.1. Systemic
    1.2. Regulations
    1.3. Public Procurement for Innovation
    1.4. Support of Private Demand
2. Supply Side Innovation Policy
    2.1. R&D Subsidies
    2.2. Support Universities and Public Research
    2.3. Pilot and Demonstration Plants

Following on defining the different possibilities RWS has to implement as policy to mitigate uncertainty, an overview is created on what procedures are in place at RWS to do so currently. The third research question is: *What procedures are in place at RWS to mitigate the in SQ1 defined uncertainties?* There are multiple procedures in place at RWS, which ones are at the innovators disposal depends on the situation the innovation is created in. We define technology push innovations, market pull innovations, and a RWS specific innovation situation called push-pull. In a push-pull one of the departments sets out a need in contest form (mostly related to one of the set goals) to which an innovation is created, which is then pushed to the actual production departments. There are two general procedures that are in place regardless of the situation. First, GPO technical experts can evaluate an innovation to assess if it complies with current regulations and are authorized to set requirements to comply with in order to comply. In this way regulatory uncertainty is mitigated. Second, are the teams that are concerned with determining what RWS's future needs will be, mitigating market uncertainty. Examples are the RWS Expedition 2050 team, the different goal teams, their road-map developers, and the Innovation Agenda team.

An analysis of the interviews and observations let to a list of 18 needs that innovators in the industry experience related to the different types of uncertainty:

- N1: innovators need a structured approach towards testing and piloting.
- N2: Innovators need RWS to articulate their needs.
- N3: Innovators indicate that they need more direct contact and interactions with stakeholders in order to reduce market uncertainty.
- N4: Innovators need organizational alignment, they need RWS to internally agree on what the needs are.
- N5: Innovators are in need of Public Procurement for Innovation (PPI).
- N6: Innovation needs to be assigned a place within the organization RWS.
- N7: There is a need for a coordinated process.
- N8: someone in charge from ideation till implementation.
- N9: There is a need for knowing who makes the decisions.
- N10: There is a need for consequences of decisions.
- N11: Innovators need structured and transparent decision making.
- N12: There is a need for professional change management that can mitigate uncertainty pertaining to the effects of "stony buyers".
- N13: Uncertainty with regards to diverse interests stresses the need a central point of contact for innovators.
- N14: Innovators are in need of adequate stakeholder management.

- N15: There is the need for regular bilateral contact.
- N16: Innovators are in need of clear and up-to-date qualification methods.
- N17: There is a need for those working on innovations within RWS to know the regulations and how to comply with them.
- N18: innovators need the other uncertainties mitigated in order to mitigate uncertainty related to time.

These 18 needs serve as the requirements for the solution that is proposed. Due to the variety of these 18 needs, no single solution could be provided and a mix of seven solutions is proposed. These solutions together form the policy mix that RWS should implement in order to mitigate the uncertainties experienced. The final answer to the research question "*How can RWS improve the mitigation of uncertainties in the commercialization of innovations in the infrastructure industry?"* therefore consists of 7 components.

The different policies are structured in an idea to launch system based on the chronological order that the innovator will benefit from them. First, an innovation intermediary will be the link between the innovator and the different RWS processes. Second, procedures for regulatory qualifications are installed. Third, pilots and demonstrations should be coordinated. Fourth, public procurement for innovation should be used to actually start buying the innovations that contribute to the set goals. Alongside these policies it is recommended to implement stakeholder and change management to assure that the organization is ready to actually implement these innovations. The final important aspect of this idea to launch system is that every time before recourses are committed to an innovation in the form of any of these policies, a review committee assess the innovation on different criteria, such as the contribution to goals.

Figure 0 visualizes the different innovation policies in the chronological order of the innovation actions of the innovators that they match to. Blue diamonds represent decision moments and orange rectangles represent RWS uncertainty mitigating actions. Blue lines indicate resource commitments and orange lines represent information flows and action handovers. In order to assure the readability of the figure the procedures already in place at RWS are not depicted.

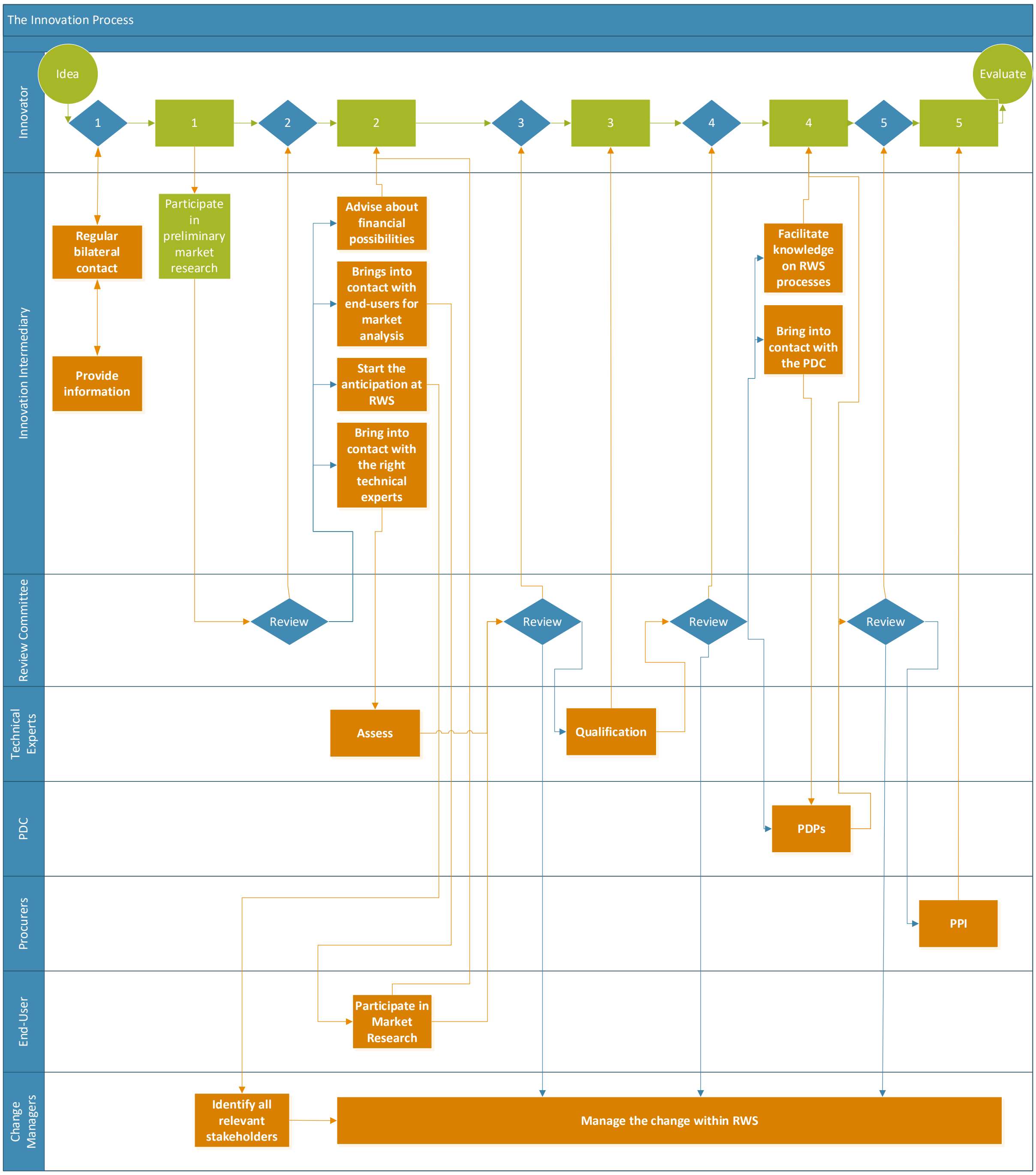

Figure 0: The Idea to Launch System for RWS

Concluding, RWS should implement a structured idea to launch system that involves the different innovation policies that can mitigate the experienced uncertainties. In this way innovations in the industry can be fostered and the goals set by RWS can be achieved. Certain procedures that are currently in place can be integrated with these new procedures, others have to be dissolved. It is recommended to focus on this structured process and have all the contacts actually go trough the innovation intermediaries so that they can assure overview and structure. Everyone within the organization should now about these structured procedures and resources should never be spend without the review committees confirmation so that they have a clear overview of what is in the portfolio and why.

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1 Introduction

Innovation in the road infrastructure industry is a topic of interest for Rijkswaterstaat (RWS). RWS is an organization that has set ambitious goals for the future, that are not achievable with incumbent technologies. This research is about RWS' innovation processes, which currently do not give the desired outcomes. To understand the setup and outcome of this research, it can be beneficial to have knowledge of the different departments RWS consists of, which units are involved in innovation, and the currently used innovation process.

This chapter shows an outline of RWS as an organization, the goals RWS has set, the industry RWS operates in, and preliminary insights in the innovation process. Following this initial context outline, the problem statement is introduced. This chapter is concluded with a thesis outline.

1.1 Rijkswaterstaat

Rijkswaterstaat (RWS) is the implementing governmental organization of the Ministry of Infrastructure and Water Management. Rijkswaterstaat provides a safe, livable, and accessible Netherlands (Rijkswaterstaat, z.d.-e). Rijkswaterstaat has approximately 9.000 employees (Rijkswaterstaat, z.d.-f) that are divided over both national and regional divisions, **Fout! Verwijzingsbron niet gevonden.**1 depicts an overview of the core responsibilities of the national departments.

Table 1: Overview of the responsibilities of different RWS departments

Department	Abbreviation	Responsibilities
Corporate Services	CD	Support the daily business of RWS in the fields of Public Relations, Human Resource Management, Legal, Finance, ICT, and Facility Management. (Rijkswaterstaat, z.d.-b)
Central Information Coordination	CIV	Arrange the enterprise systems and business information systems in place within RWS. (Rijkswaterstaat, z.d.-a)
Big Projects and Maintenance	GPO	Provide the infrastructure in the Netherlands. (For projects that do not fit the budget and scope of the region.) (Rijkswaterstaat, z.d.-c)
Programs, Projects, and Maintenance	PPO	Maintenance of the majority of the structures RWS has in its portfolio. (Rijkswaterstaat, z.d.-g)
Road- and Water- Traffic management	VWM	Bundle the management of Road- and Water- Traffic, RWS aims to standardize its services to enhance the user experience. (Rijkswaterstaat, z.d.-h)
Water, Traffic, and Living Environment	WVL	Anticipate opportunities and challenges, knowledge management &monitoring, creating a vision for the future. (Rijkswaterstaat, z.d.-i)

Regions		Regions are responsible for the asset management in their region.

1.2 Determining Priorities

Society is changing rapidly and new technologies develop fast. RWS is responsible for infrastructure that suffices the needs of the public. Concrete goals in line with the public needs are formulated to ensure that efforts at RWS are aligned and the budget is managed. At RWS the goals that are marked with high priority are known as the focus points, following, these focus points will be introduced (*Innovatieagenda 2030*, z.d.; RWS & Dialogic, 2019).

The first goals are about sustainability. The aim is to generate all the power needed for all the activities from their own renewable sources, to have zero CO2 emissions, and to be fully circular by 2030. In 2019 the ministry of infrastructure and all the related organizations, such as RWS, produced 113 000 tons of CO2, which is 36% less than in 2009 (Rijkswaterstaat, 2020). Important to note here is that RWS is not constructing anything themselves, the private organization that does the factual construction emits the CO2 that is related to the construction of the infrastructure. The private organizations in the industry emit another 612 000 tons of CO2 in 2019 (Rijkswaterstaat, 2020). These emissions are excluded from the zero-emission ambition of RWS and are subjected to other goals. The emissions in the industry can be divided into 4 sub-categories. Water management is responsible for 31% of the emissions, 12% comes from machinery, 33% from asphalt, and 24% from objects like bridges and tunnels (Rijkswaterstaat, 2020). In 2017 the construction industry (including both infrastructure and real estate) was responsible for 2% of all the CO2 emissions in the Netherlands (CE Delft, 2019).

Secondly, a major challenge is coming up for RWS as most of the infrastructure was built after the second world war and is now reaching the end of its expected lifetime. The preference lies in only replacing and renovating what is needed when it is needed. Innovations are needed to ensure that the replacing and renovating happens quick, resource efficient, and sustainably.

The final goals are related to digitalization and focus on Smart Mobility and Data. IoT is becoming more important, as well as data platforms, and autopilots. Data collection needs to be standardized so that the data can be used more easily, the data can then be used to support the core tasks of RWS.

To obtain these above-mentioned goals, RWS needs innovations. Incumbent technologies are not able to satisfy the needs that RWS expresses with these goals. RWS is only the manager of all the infrastructure all the construction and maintenance is done by private organizations in the transport infrastructure industry. It is therefore that the companies in the industry need to innovate in order for RWS to achieve the set goals.

1.3 The transport infrastructure industry

Between 1945-1970 the Dutch government actively invested in the infrastructure as the country had to be rebuilt after the war and the population of the Netherlands was growing rapidly (OECD, 2001). After that period, the focus shifted from building to maintenance. After 1990, building new infrastructure became the focus again. For this new building spree the approach is to co-invest with private organizations in the sector and to realize public/private partnerships. Public procurement was reinvented creating more possibilities for collaboration with private organizations. Starting from 2002 procurement gradually changed from traditional approaches towards tenders with detailed functional requirements and assessment on price and quality (McKinsey & Company, 2019).

In modern day procurement RWS uses a variety of contract types, that can be fitted to the situation at hand. Frequently used new contract forms are DBFM, D&C, and Prestatie. DBFM is the abbreviation of Design, Build, Finance, and Maintain. These DBFM contracts encompass the complete project life cycle and have a contract term of 20 years on average. D&C denotes contracts in which the contractor is responsible for the Design and Construction for the project. In Prestatie contracts the contractor is responsible for the conservation and maintenance of the agreed areage for a period of three years. An upcoming contract form is DBM, Design, Build and Maintain, which is used as a replacement of the DBFM contracts that turned out to be too constraining for the companies in the industry (Interviewee C).

The road infrastructure industry comprises of RWS, provinces, municipalities and private organizations such as Schiphol. On the demand side of the industry RWS is responsible for 65% of all the tenders in the industry, and for projects larger than 250M, RWS is the only client. On the supply side of the industry, the largest 10 companies comprise 50% of the industry. Therefore, the market is imperfect (McKinsey & Company, 2019). According to McKinsey & Company (2019), RWS should rethink the free market principle, divide the risks differently, and stimulate innovation to create a more sustainable industry. Furthermore, the industry needs to improve the signaling, mitigating, and managing of risks (McKinsey & Company, 2019).

The market is imperfect and companies in the industry endeavor financial distress. The profit margin of the 8 largest construction companies in the Netherlands is 0.03% on average (McKinsey & Company, 2019). As a consequence, only limited resources can be spent on R&D and Innovation. When recourses are spend on innovation, companies in the industry experience difficulties to generate a return on those investments (McKinsey & Company, 2019).

1.4 Innovation and RWS

RWS is facing multiple challenges that affect the core operations. In the coming years, all the infrastructure that was built after the second world war needs replacement or renovations as their lifetime will expire. RWS is committed to decreasing its impact on the climate, taking into account greenhouse emissions, biodiversity, fish populations, waste management, and other aspects of sustainability. Incumbent technologies will not suffice to obtain the set goals and therefore RWS requires innovations that contribute to the set goals.

The innovations needed for achieving the set goals are developed by private organizations in the industry. RWS can influence the availability of innovations that are available with a variety of policies and actions. Currently, multiple different initiatives are committed to increasing the number of innovations that are available in the market to contribute to the goals. The coordinating role is in hands of the Corporate Innovation Program (CIP) (Interviewee E, R, T).

1.4.1 The Corporate Innovation Program

The corporate Innovation Program has a coordinating role regarding what kinds of innovations are of interest for RWS. The Corporate Innovation Program (CIP) is in charge of organising the process of the Innovation Agenda (Internal and External) and the Innovation Implementation Agenda which communicate the vision and goals for innovation. The CIP constructs the advisesd content of the vision and goals that are eventually set by the board of RWS.

The CIP is a multidiciplinary team in which employees from all the different departments elaborated in Table 1 take place. Within the organization, the CIP is positioned in the WVL department. Most eployees in the CIP take on this role next to their function in one of the departments. The CIP works with focus point teams that each concerns their own of the in section 1.2 introduced goals and with transition path teams that are each concerned on transitioning a certain part of the infrastructure, such as asphalt.

The CIP also tries to coordinate some of the RWS efforts that regard how innovation is done. Figure 1 depicts the innovation process at RWS as seen by the CIP (RWS & Dialogic, 2019). It shows that innovation can either take place while working on a project (denoted by the dark blue area) or in a more general innovation process outside projects (denoted by the light blue area). The figure also depicts that innovations that are incorporated into projects have to be based on proven technologies. The figure introduces the Innovation Loket which will be discussed in Chapter 6.2.

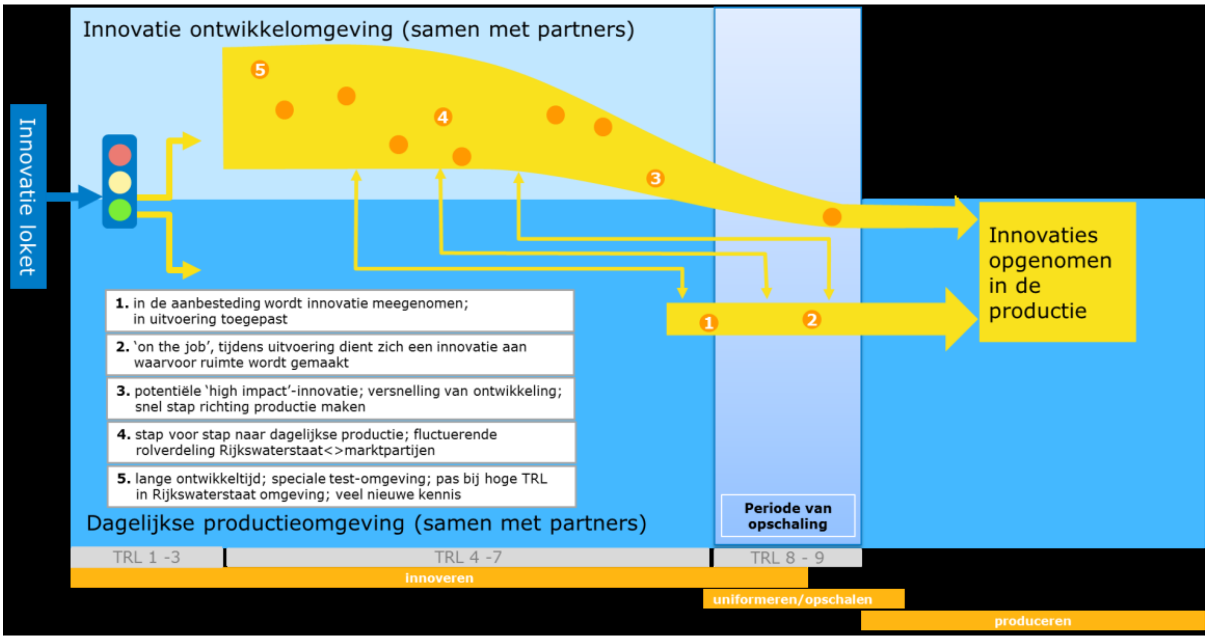

Figure 1: RWS distinguishes two different innovation pathways, based on when the innovation is initiated (RWS & Dialogic, 2019).

At the bottom of figure 1, three terms are used to describe the innovation process. First, *innovate* describes the phase in which the idea is created and tested. Secondly, *uniform* describes the phase in which the innovation is scaled-up. Finally, the innovation will be in the *production* phase in which the innovation is accepted and used throughout the organization. The figure also depicts the TRL levels that innovations are supposed to be in when they are in one of those 3 categories according to the CIP. Figure **Fout! Verwijzingsbron niet gevonden.**2 shows a preliminary decision model (in Dutch).

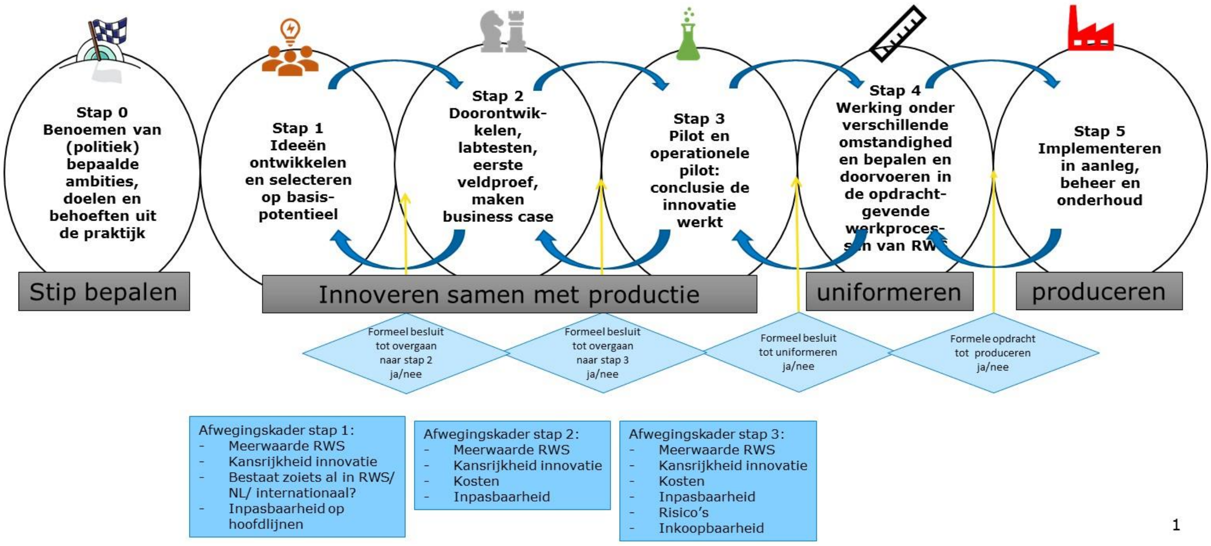

Figure 2: Preliminary decision model for the innovation process (Internal Documentation).

1.5 The Problem

The goals defined in section 1.2 are set to create a safe, livable, and better connected Netherlands. However, with the incumbent technologies that are currently available in the industry, RWS is not going to obtain those goals. When the industry fails to develop the right innovations, RWS fails to obtain the goals, which would be a problem.

Currently, the expectation is that not enough innovations will be mature in time to achieve all those set goals. The problem analysis shows that it is assumed that a sufficient amount of ideas are generated in the industry and that the problem lies with maturing the innovations. Those same conversations show that employees experience a lot of problem trying to mature innovations. Innovations get stuck in the maturation process, while they do have potential. Reoccurring problems that employees mention are; being punished for mistakes and not receiving recognition for trying nor for successes, and that it is often unclear who is authorized or responsible to make decisions. There is a fear for failure and so for being responsible for mistakes. Another important topic is the lack of time, budget, or other recourses to spend on innovation. These findings from exploratory conversations are confirmed by internal documentation.

"*This is the barrier that is regularly encountered: production (or operation) is not eager to take extra risks and to organize space, time and possibly extra money. Our challenge now is to break down that barrier by better arranging scaling up by making agreements and finding financing to be able to go through this process of scaling up. As a result, we can achieve more upscaling and ultimately inclusion in the daily production.*"[1] (RWS & Dialogic, 2019)

Another important issue in the above citation is that decision-makers are not eager to take on additional risks. That statement is also aligned with the other findings from exploratory conversations, as a lack of commitment of resources or the preference not to be responsible for something, are closely related to people's perception of risks and uncertainties.

[1] This quote is translated, the original language is Dutch

Risks and uncertainties technically are two different things, although it is common practice to use the terms interchangeably. Risk is when enough information is known to calculate probabilities for different outcomes and uncertainty is when there is so little information available that probabilities cannot be calculated and not all possibilities can be overseen (Knight, 1921).

People are generally risk and uncertainty averse and prefer the status quo (Day & Schoemaker, 2000; Jalonen, 2011). Uncertainties that surround innovations cause delayed decisions and semi-commitments (Day & Schoemaker, 2000). People put the burden of proof on those who want something new or changed and sticking with the familiar is one of the pitfalls when it comes to adopting innovations (Day & Schoemaker, (2000). Other pitfalls are the reluctance to fully commit, the lack of persistence, and delayed participation. The risk aversive organizational culture in the public sector is, among other things, fostered by the political damage for elected officials in case of failure (Arundel et al., 2019).

Because of the uncertainty aversion, managing uncertainties is essential to mature innovations (Fabris et al., 2017). The innovation process is a process of reducing uncertainties (Bohn, 2005; Bonnín Roca et al., 2017; Jalonen, 2011; Vincenti, 1990), thus improving the uncertainty management will therefore foster the maturation and commercialization of innovations in the industry.

Decision-makers tend to avoid situations where uncertainty is high (Day & Schoemaker, 2000; Jalonen, 2011), which indicates that the preference of incumbents over innovations can be mitigated by improved uncertainty management. The report by McKinsey & Company (2019) emphasizes that incumbent technologies are chosen over innovations by decision-makers at RWS because of the uncertainties, in combination with RWS mainly focusing on costs.

"Due to a combination of cost management by clients and the uncertainty of the performance of (often more expensive) innovations, there is an incentive to choose known solutions and the willingness to invest in innovation by third parties is limited."[2] (McKinsey & Company, 2019)

Concluding, final decision-makers expect completely developed and riskless innovations to be delivered to them, while in real life, a complicated process of uncertainty reduction needs to take place before that is possible. On the other hand, innovators expect their ideas to be welcomed with enthusiasm, as their ideas could contribute to RWS' long-term goals. There is a gap between those two places in time and maturity, innovations end up in that gap and have troubles coming out. In internal documentation, the problem is stated to be in the scale-up phase of the innovation process, explained to be the phase between a first test and general use.

To close the gap, all kinds of programs, units, and departments are installed. Most of these initiatives are bottom-up and based on individuals' ideas and motivations. There is a broad group of RWS employees that see the need for innovations and the need to support the private organizations in the industry in their innovation processes. However, these efforts have not resulted in the desired accretion of innovations contributing to the goals. The initiatives are uncoordinated and do not connect into one smooth innovation process. The initiatives fail to foster ideas into the production, they fail to reduce the uncertainties that surround the ideas. When uncertainties stay too high the new ideas will not be used by the departments that are responsible for the final decision making.

Following the above explanation, the consolidated problem statement is:

[2] This quote is translated, the original language is Dutch.

RWS needs innovations to create a safer, more sustainable, and better connected Netherlands. However, innovations in the industry do often not scale-up and commercialize as known and trusted incumbent technologies are often preferred.

Multiple previous internal studies have tried to analyze similar problem statements from multiple perspectives. Examples of previous angles used to solve the problem are stakeholder alignment and ecosystems (Dekker, 2017), information management and feed-back and -forward (Grunewald, 2020), and innovation systems (SSU Foundation & RWS, 2020). A first discovery of internal documentation and informal conversations shows that an uncertainty management perspective has not been the subject in previous research and contributes to the existing available knowledge at RWS, it therefore is a suitable perspective.

Uncertainty mitigation requires efforts from multiple specialties within RWS such as the CIP, who commissioned this research. ITC, PPO, GPO, and the other departments described in this chapter are examples of departments that are involved, different kinds of uncertainty could need different departments to reduce them. The findings of this research should help the CIP define the innovation processes and design the efforts needed to mitigate uncertainty across the organization.

1.6 Thesis Outline

This thesis consist of 10 chapter, a brief introduction of each of the consecutive chapters will follow. First, in chapter 2 the research questions that follow from this introduction are introduced. Consequently, the research methodology used is described in chapter 3. In chapter 4 the different types of uncertainty will be introduced. Chapter 5 explains potential public innovation policies that RWS can implement. Chapter 6 shows which procedures to mitigate uncertainty are in place at RWS. Chapter 7 lists the needs with regard to the in chapter 4 defined uncertainties. Chapter 8 presents the proposed solutions for those needs. In chapter 9, the limitations of this study and the directions for further research are elaborated. Finally, the conclusion is presented in chapter 10.

2 Research Questions

This study aims to support RWS in designing an innovation process that foster innovation in the industry. RWS has set ambitious goals, now RWS needs innovations to achieve them. Therefore, RWS is concerned with innovations in the industry. Innovations in the industry do currently not commercialize for different reasons, uncertainties surrounding the innovations being the one of interest. The following research question aims to find causes, needs and solutions related to these uncertainties.

The research question is:

How can RWS mitigate uncertainties inherent to innovations in the infrastructure industry?

To be able to answer the research question and to solve the problem, multiple sub-questions are formulated below.

Reducing the uncertainties surrounding innovations so that they can scale-up and commercialize requires an overview of which uncertainties are important in the innovation process. The starting point of this research is creating an overview of the different uncertainties present during innovation.

SQ1: What are the main uncertainties that affect the upscaling and commercialization of innovations?

RWS is the implementing organization of the Ministry of Infrastructure, a public organization that can create innovation policy. Innovation policy is the actions of a public organization influencing the innovation process (Mazzucato, 2017) and thus can potentially help to overcome the uncertainties as defined in SQ1 and advance the scaling-up and commercialization of the innovations. It is of importance to determine what policies can be used, and how this can influence the scaling-up and commercializing of innovations in the industry.

SQ 2: What is the role that public organizations like RWS and their public policy can play in overcoming uncertainties?

Answering SQ1 and SQ2 gives insights into the relevant developed theories. In order to formulate an advice that applies to the specific situation of RWS and to improve the innovation process so that it reduces uncertainties adequately, it is important to understand the current situation, what procedures to mitigate uncertainty are already in place.

SQ3: What procedures are in place at RWS to mitigate the in SQ1 defined uncertainties?

This research focuses on uncertainties. RWS exploits the public value created by innovations, but the private organizations that developed them eventually have to generate profit from the innovation. The perspective of the private organizations on the mitigation activities are important as a positive outcome only results if both parties can reap the desired benefits. In the following SQ, the perspective of the private organizations is taken into account. Do the RWS initiatives as found in the previous SQ affect the innovation process as they intend to do, are those intentions in line with the needs, and is the collection of those initiatives enough, or are certain aspects of the innovation process in need of more involvement?

SQ4: To what extent do the procedures in place at RWS meet the uncertainty mitigation needs of innovating private organizations?

The theoretical and empirical findings together form the basis to formulate advice for what the by RWS practiced innovation policy should look like. Advice will be generated that could help solve the problem RWS is facing.

SQ5: How can RWS improve the mitigation of uncertainties in the commercialization of innovations in the infrastructure industry?

3 Research Methodology

This chapter explains the methodology used to answer the before-mentioned research questions. The methodology used in this research is grounded theory. Grounded theory is used to formulate advice about a studied phenomenon and is often used to conduct studies on social processes such as the formulation of public policy (Charmaz, 2006). This methodology will be explained in detail below. The mixed-methods approach for collecting data will be explained afterwards and that section will be concluded with the explanation of the focus group that I will use to test the constructed solution.

This research is conducted in multiple iterative steps. First, an exploratory empirical study was conducted to identify the problem at hand. Secondly, literature was sought to define and elaborate on the specifics of the problem and identify solution directions. Third, an empirical study was conducted. Then the second and third step were iterated until the desired outcome. Following, the empirical and theoretical findings were used to induce an improved innovation process. In this step new literature was sought to specify the solutions. Finally, this newly generated innovation process was subjected to a focus group to evaluate it.

This chapter elaborates the different aspects of this research. First, the basis of grounded theory is introduced and it is elaborated why grounded theory suites the problem statement at hand. Secondly, the different aspects of the quality of this research will be discussed as well as how the quality will be assured. Third, the different types of data collection used are explained. Finally, the data analysis procedures are clarified.

3.1 Grounded Theory

Grounded theory is an inductive method, meaning that I will study individual cases and then induce concepts and theories from that. The idea of grounded theory (Charmaz, 2006; Glaser & Strauss, 2017; Thornberg & Charmaz, 2014) is to continuously build on what has been found before. Interviews, conversations, and observations are the important ways of data gathering, and this data gathering is an iterative process. If new insights come to light it can be beneficial to re-interview someone with that new knowledge. The key is to constantly compare and build on all the knowledge that has been gathered before.

In grounded theory feelings, views, intentions, and actions are of importance (Charmaz, 2006). The uncertainties, that are the focus of this research, do not impact the maturation of the innovations directly, the innovations are impacted by people that experience uncertainties. Therefore grounded theory fits researching uncertainties and their impact on the maturation of innovations.

Grounded theory research is often used to conduct studies on social processes, such as the formulation of public policy, focusing on what people do and what the meaning of their actions is. In this study, the focus will be on the actions of the people in the innovation departments and the aim is to construct a solution for the uncertainty reduction, fitted for the implementing organization RWS.

Charmaz (2006) does recommend delaying a literature review in the case of grounded theory and initially go into a situation blank so that new theories can be synthesized. Despite this advice, the theory will come first in this research as a certain knowledge base is needed to be able to ask the right questions in interviews. All the basic knowledge or, as defined by Glaser & Strauss (2017), "*the beginning foothold*" needed for this research and the formulation of a theory, can be found in the answers of SQ1 and SQ2.

3.2 Research Quality

The important criteria to determine the quality of research are controllability, reliability, and validity (Van Aken et al., 2012). To achieve high-quality research these three aspects have to be controlled. It is therefore that they are taken into account for the design of this research.

Controllability. Controllability is a prerequisite for the evaluation of the other two quality factors, it requires researchers to provide a detailed description of the study so that it can be replicated (Van Aken et al., 2012). Apart from providing the possibility to replicate the study, it also allows others to check how the study was conducted and by that to assess the reliability and validity.

Reliability. The results of a study are reliable when the successful replication is independent on the particular characteristics of the study. There are 4 types of characteristics that a study can depend on: the researchers, the instrument, the respondents, and the situation (Van Aken et al., 2012).

The dependency on the researchers can be reduced by standardization or the use of tools. As standardized and structured interviews would not suit this study, the use of tools such as QDA Miner light for data analysis is of importance. Reliability is also increased by the use of multiple different data collection instruments, such as interviews, observations, and internal documentation in this study. With regards to respondents, it is important to involve all different roles, departments, and management levels. Increasing the number of respondents can also increase reliability. Current situations can influence the problem at hand or the respondents' opinions, this study will be conducted over a long period and can therefore limit the influence of specific situations.

Validity. Validity is defined as the best approximation to the truth, including the propositions about causation (Cook & Campbell, 1979). Construct validity is the extent to which a measuring instrument measures what it is intended to measure. To achieve a high construct validity the concept should be covered completely and the measurement should have no components that do not fit with the meaning of the concept. Internal validity is about the characteristics of the research and can be achieved by the right research design, external validity regards the generalizability to other settings (Campbell & Stanley, 1963). External validity is not much of a concern in problem-solving research such as this one(Van Aken et al., 2012), the findings of this study do not need to be generalized. It will follow in chapter 5 that there is a high need for context-specific and tailored outcomes in this field of innovation policy design.

For grounded theory four different criteria are important to take into account (Blumberg et al., 2014). First is the **fit**, meaning that I represent the real incidents which is assured by interviewing a broad set of employees throughout the organization. Second, the **relevance** for practice, in this study the relevance is assured by the RWS guidance. Third**, does the prescribed recommendation work**? Testing this in real-life would be beyond the scope of thesis and therefore a focus group will be used for preliminary testing. Fourth, **modifiability,** which concerns the ease with which the recommendations can be adapted to new insights.

3.3 Data Collection

In this chapter, the different types of data collection used for the different sub-questions are explained. Data was collected in the form of exploratory conversations, literature, interviews, internal documentation, participant observations, and a focus group session.

3.3.1 Exploratory conversations

In order to write this thesis, a clear understanding of the organization RWS and the problems at hand had to be developed. In order to arrive at a comprehensive understanding of the organizations and the problems experienced by the different departments, more than 31 hours of explorative conversations with more than 50 RWS employees have taken place. This data was used to develop the problem statement. These conversations were conducted with employees from different departments or subdepartments such as NOVA, GPO Innovation and Market, WVL, WVL CIP, LEF, Regions, and Goal teams.

3.3.2 Literature

The beginning foothold needed for this study can be generated from theory. SQ1 regards the types of uncertainties that affect innovations, the general concepts can be derived from theory after which the RWS practice can be added from empirical work. SQ2 regards the types of innovation policy to overcome uncertainties, which can be found in literature. These formed the starting point to ask the right questions and to find the right angle.

First, an overview of the uncertainties and their effect on innovations in the industry were created. Subsequently, innovation policies that can mitigate those uncertainties were gathered from the literature. The search was limited to innovation policy that can be practiced by RWS, the focus is on collaboration with the industry. After these two steps of collection literature, different kinds of empirical data were gathered before returning to literature again. The second round of literature collection mostly regarded SQ5.

This literature searches were not systematic nor all-encompassing, the literature review created a basis of knowledge about the topics of interest in the research.

3.3.3 Interviews

In grounded theory, empirical findings are of great importance. Interviews were used to answer SQ1, SQ3, SQ4, and the answers given there were an important source for the answer to SQ5 too. For this study, multiple interviews took place to gather data. To find the right interviewees a combination of snowball and theoretical sampling was used.

Coleman (1958) defines snowball sampling as an iterative process in which interviewees are asked who to interview next. Biernacki & Waldorf (1981) find that snowball sampling is especially valuable in cases where it requires insiders to locate the people of interest. This is the case at RWS as it is a big organization with scattered innovation efforts. Blumberg et al. (2014) specify that snowballing is especially useful when sample subjects are hard to identify as they are not categorized in a certain population. This is the case at RWS as the employees working on innovation are not in one team or in one department.

Theoretical sampling is a technique specifically used for grounded theory in which the aim is to find interviewees that could attribute to the theory, more that to assure that interviewees from different sub-groups are represented (Blumberg et al., 2014).

The intention was to interview innovators whose innovations made it to implementation already, innovators whose innovations are currently on-hold or awaiting decisions from RWS, and innovators whose innovations are currently tested. Interviewing innovators turned out to be more complicated than estimated. The snowball technique, using RWS employees to refer to innovators, did not give the desired outcomes.

Fifteen RWS employees as well as five innovators participated in this study in the form of official interviews, appendix A gives an overview of the participants and some of their identifying characteristics. These interviews were semi-structured.

The participants were first questioned about what uncertainties they identify in the innovations they work with. Secondly, interviewees elaborated on what RWS is currently doing to reduce uncertainties. Finally, the innovators told their perception of the current collaborations, their needs, and the discrepancies between those regarding uncertainties.

3.3.4 Internal Documentation

Internal documentation was accessed through interviewees and supervisors. Internal documentation can support the findings from interviews and can give a broader view of the situation. The documents can describe specific cases or processes in detail. Internal documentation can also give insights into the general environment such as the documents by Dialogic and McKinsey. Internal documentation has been used for the introduction, SQ3, and SQ5.

3.3.5 Participant Observations

During this research, I was invited by my supervisors to attend meetings regarding innovation. These meetings were organized by the CIP and regarded the current Innovation-Uniform-Production (IUP) innovation model, in these sessions three important innovations that are currently being worked on were discussed and evaluated. These observations contributed to SQ1, SQ3, SQ4, and SQ5.

These meetings were used to obtain valuable data about the innovation process in place at RWS and the effectiveness of the actions. Observing meetings can provide data on who is involved in the processes of interest (Kawulich, 2005; Schensul et al., 1999), and following from that, who could be interesting interviewees. Observations can also bring to light how the organization works and what cultural parameters are (Schensul et al., 1999). Participant observations can be used to observe proceedings that individuals might not want to state in interviews because they are sensitive or political topics (Marshall & Rossman, 2014). RWS is the implementing organization of the ministry and therefore there is a lot of politically sensitive issues. Adding observations to a study based on interviews will create a more holistic view and give a better understanding of the context (DeWalt & DeWalt, 2011). From the observations in this study information about the uncertainties that people experience, the ways RWS handles them, and how certain people want them handled were retrieved. Other subjects with less relevance for this study will not be incorporated in the findings elaborately.

These observations were also valuable because people could struggle to identify uncertainties they encounter as uncertainty, observing participants identified those uncertainties that interviewees might not themselves. Observations also assessed the effectiveness of the actions taken by RWS, as individuals who actively take actions in the innovation process might be biased about their work.

3.3.6 Focus Group Session

In a focus group, multiple interviewees are questioned at the same time, discussion among them can take place and interviewees can add to each other's answers (Folch-Lyon & Trost, 1981). The intragroup stimulation results in more gathered data from 1 focus group than from individual interviews with the same participants (Folch-Lyon & Trost, 1981). The focus group consisted of people that are affected by the generated advice and employees that are responsible for generalizing processes at RWS. Morgan (1996) finds that smaller groups are more appropriate in cases of high participant involvement as there will be more time to speak for each of them. The consequence of a limited number of participants results in a limited number of opinions. An installed moderator asked the participants about their opinion to ensure all opinions are voiced.

When using a focus group it is important to realize the influence of cultural factors and social structures that influence the responses (Folch-Lyon & Trost, 1981). When participants are accompanied by others from the same social group, it can be that they adhere their responses to the norms of the group. It is important to take this into account when selecting the participants. As these will all be RWS colleagues in a dependent innovation process, there will be a certain need to adhere to the social norms.

In the focus group used in this study five RWS employees participated, the findings were presented and a moderator was present. Seven employees were invited. The group was mixed, with employees that had and had not been interviewed and work in different departments.

3.4 Data Analysis

The in the previous subsection described data types were used in this research in different steps. Following, each of the steps will be explained and the types of data will be connected to the steps.

The first step of this research was a problem analysis in which the explorative conversations were used to comprise a problem statement. The second step was the creation of the beginning foothold in which literature was studied to create a preliminary theoretical answer to SQ1 and SQ2. This beginning foothold was then used in step 3, where interviews and participant observations were used to comprise a more specific answer to SQ1 and an answer to SQ3 and SQ4. Fourth, the empirical findings for all the above SQs were combined with literature that fitted the specific instances found in practice. Fifth, the answers of the research questions were used to identify which literature would be needed to design a solution and the solution was designed using that literature. Finally, the recommendations were subjected to a focus group to do an initial review of the usability of the developed solutions.

For the analysis of the interviews and participants observations, the constant comparative method (Glaser & Strauss, 2017) was used. In this method, the coding of newly generated data took place simultaneously with the analysis of the data. In practice this means that new data was codes right away and the insights were immediately taken into account for the next interview or observation.

Coding is "naming segments of data with a label that simultaneously categorizes, summarizes, and accounts for each piece of data" (Charmaz, 2006)

The constant comparative method (Glaser & Strauss, 2017) has four general stages that are not solely consecutive. It is an interactive process, when proceeding to the next stage activities from the first stage will still take place. In the **first** stage, new data was coded into a category. In the **second** stage, the initial data was compared with the use of the codes, and memos were written about the similarities. In the **third** stage, the constant comparison reduced the terminology, increased the level of generalizability, and decreased the number of categories of codes. In the **fourth** stage, the analyses were all gathered into a reasonably accurate statement about the topic, an advice in the case of this research.

Thornberg & Charmaz (2014) define a **first** phase of coding was initial/open coding. In this phase the contextual codes in appendix B arose. Coding in the **second** phase was focused coding. "Focused coding is more directed, selective, and conceptual than initial coding" (Thornberg & Charmaz, 2014). In this second phase, the codes were matched with the knowledge from the beginning foothold and clusters such as the middle and higher order codes in appendix B were constructed. The clustering process was partly done by using multi-colored sticky notes on the wall, indicating overarching themes, making categories of the codes. After an iterative process of coding, repositioning sticky notes, and recoding, in which codes were renamed and merged, all findings have been concluded. The **final** phase was theoretical coding, in which the advice was formulated from all the coded data. Appendix B is a list of all the codes that arose after the iterative coding process.

Figure 3 shows the iterative process of data collection and analysis towards the generation of the final advice. In the figure data was gathered repeatably from interviews and observations, as well as that internal documentation was reviewed. While doing so memos were written.

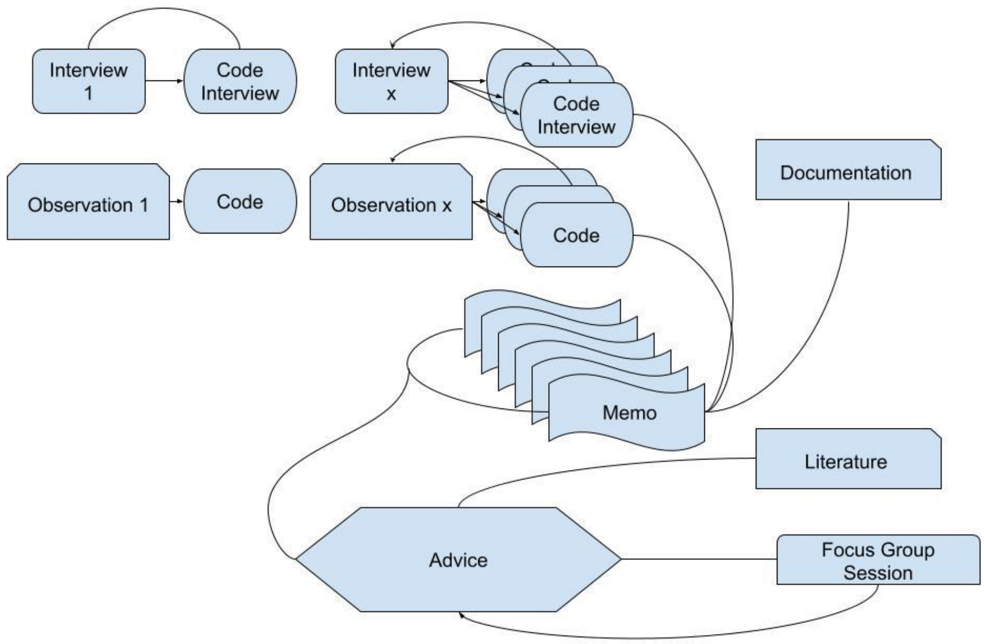

Figure 3: Research process

4 Uncertainties affecting Innovation

The first sub question of this thesis regards the different types of uncertainty that are inherent to innovation and could affect the maturation. First, a clear definition of what uncertainty is and why it affects innovations is presented. Consequently, this chapter will thoroughly elaborate the different types of uncertainty using both literature and the RWS practice. This chapter answers SQ1: *What are the main uncertainties that affect the upscaling and commercialization of innovations?*

Innovation is a new product or process, the novelty of the product or process causes certain unknowns. Some of these unknowns can be estimated by innovators, while others cannot. Knight (1921) distinguished these two categories of unknowns and coined them 'risk' and 'uncertainty'. Risk is when enough information is known to calculate probabilities for different outcomes. Uncertainty is when there is so little information that probabilities cannot be calculated and not all possibilities can be overseen.

Decision-makers at firms tend to avoid situations where uncertainty is high (Day & Schoemaker, 2000; Jalonen, 2011). When risk and uncertainty aversion is high, organizations may avoid the adoption of innovations until the uncertainties are dissipated, and prefer the incumbent technology during that time. Managing uncertainties therefore is essential to mature innovations (Fabris et al., 2017). As innovations mature, information is acquired about the innovation and the level of uncertainty is decreased in that way. The cause and effect relationships of the different aspects of the innovation start to become more clear as the innovation matures. Concluding, the innovation process is a process of reducing uncertainties (Bohn, 2005; Bonnín Roca et al., 2017; Jalonen, 2011; Vincenti, 1990).

There are many types of unknowns present in the innovation process. Jalonen (2011) defines eight different types of uncertainty that affect innovations: Technological Uncertainty, Market Uncertainty, Regulatory/Institutional Uncertainty, Social/Political Uncertainty, Acceptance/Legitimacy Uncertainty, Managerial Uncertainty, Timing Uncertainty, and Consequence Uncertainty. Cantarello et al. (2011) make a more general categorization and define only technological uncertainty, market uncertainty, and behavioral uncertainty. Combining the two above-mentioned classifications, it follows that technology uncertainty and market uncertainty are both important types of uncertainty that are directly connected to the innovation. The uncertainty about the consequences of the innovation will therefor become a subcategory of technological uncertainty and the uncertainty about the acceptance become a subcategory of market uncertainty. Following, the uncertainties are categorized in six groups, these six types of uncertainty will be used as a structure to connect all the policies, procedures, and recommendations with.

Figure 4 shows the different types of uncertainty in the above categorization. The dark blue squares indicate a main uncertainty category as derived from literature. These dark blue squares also correspond to the relevant highest order codes in appendix B. When elaborating these main categories in the following sub sections, the light blue squares are sub categories derived from literature that are actually experienced in practice. These light blue squares correspond with the middle order codes in appendix B. The light blue parallelograms are RWS context specific aspects of the uncertainty. The parallelograms correspond with the contextual lowest order coding in appendix B. Be aware that the contextual coding in the parallelograms arose from a first round of coding interviews with a bottom-up approach. The final naming of the categories sometimes did cme from literature as they appeared there too. The squares came from a second round of coding in which the contextual findings were grouped using the knowledge from the beginning foothold.

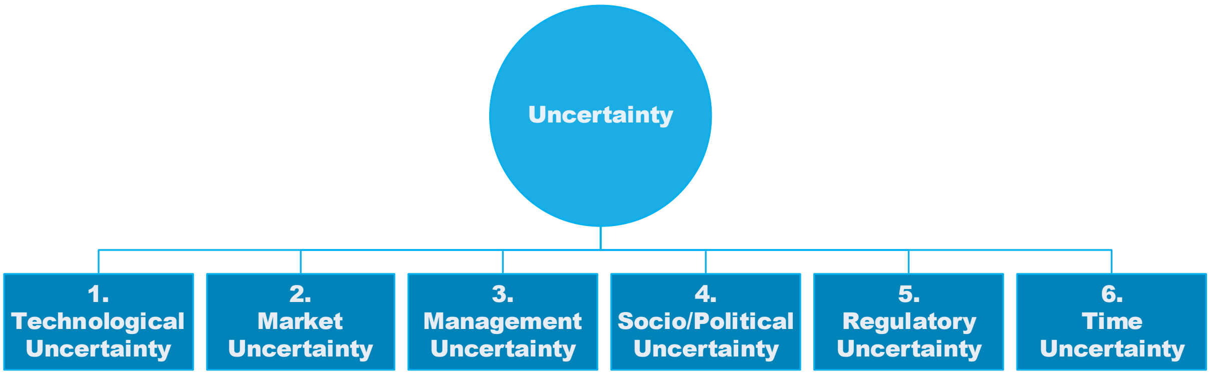

Figure 4: The different types of uncertainty based on the classification by Jalonen (2011)

4.1 Technological Uncertainty

Technological uncertainty is directly related to the specific innovation, multiple perspectives on the definition of this uncertainty will follow below. Jalonen (2011) defines technological uncertainty as uncertainty coming from the *product specification* or the *production processes*. He states that the uncertainty is dependent on the novelty of the technology. From a different perspective, Cantarello et al. (2011) define technology uncertainty as to when new skills and competencies have to be gained to explore new technologies. Chakravarthy (1985) and Steensma & Fairbank (1999) agree on technology uncertainty being not knowing if the innovation will work as intended, until it is fully developed, tested, and in specific cases, implemented. Bonnín Roca et al. (2017) point out that in the early stages it can also be unknown why something does or does not work as intended. An important note is that when a technology matures, the uncertainty decreases from unknown, to tacit knowledge to codified knowledge. Figure 5 shows the decrease of technological uncertainty over time and more importantly learning. Concluding, technological uncertainty is all uncertainty related to the **functioning**, **use**, and **development** of the innovation.

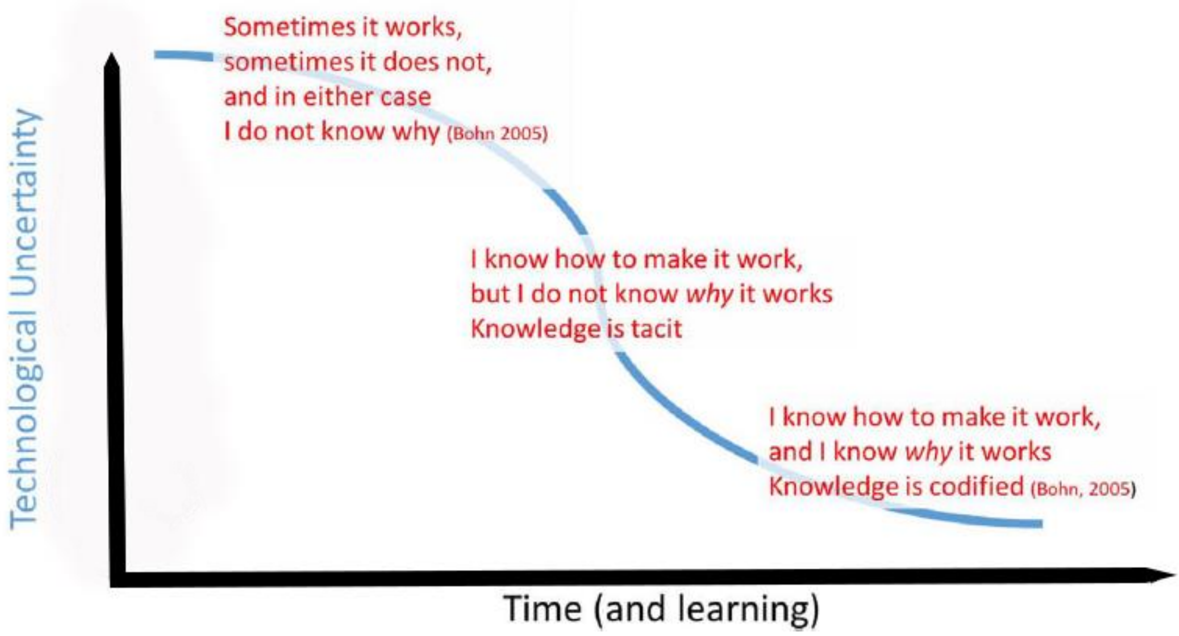

Figure 5: The decrease of technological uncertainty in the innovation process. Adapted from Bonnín Roca et al. (2017)

Contributing to the findings from the literature, the same three categories of functioning, use, and development technological uncertainty can be derived from this empirical study. Figure 6 shows the different subcategories of technological uncertainty that will be elaborated in the following subsections.

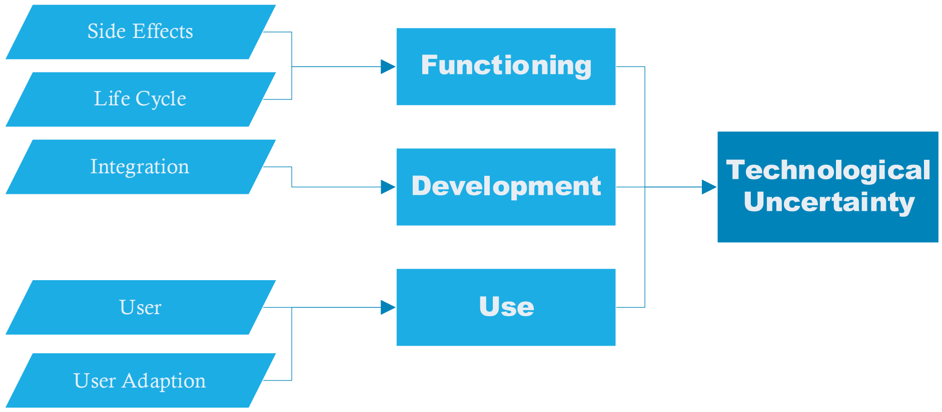

Figure 6: Subcategories of Technological Uncertainty. Based on: Interviews and Bonnín Roca et al. (2017); Cantarello et al. (2011); Chakravarthy (1985); Jalonen (2011); Steensma & Fairbank (1999)

Both MacCormack & Verganti (2003) and Shenhar et al. (1995) argue that it is important for innovators to realize what scale of technological uncertainty they will face as the different levels need different types of innovation efforts such as resources, organization, and coordination. The efforts should be aligned with the level of uncertainty to be able to scale up the innovation.

In the road infrastructure industry, most innovations have Low Technical Uncertainty as they rely on well-established technologies, that are widely available (Shenhar et al., 1995). The uncertainty that is of great importance for the road infrastructure industry is the uncertainty if the product will be safe for a long period.

4.1.1 Functioning

The functioning of an innovation is a source of uncertainty that is of importance in the road infrastructure. When innovations do not function as supposed it is the government that is held accountable for casualties and costs, while the population as a whole becomes a victim. Therefore, RWS has strict requirements in place concerning safety. Interviewee G elaborates that being held accountable for public safety and public spending changes the willingness to take on risks and uncertainties.

"Innovators want to make something nice and you have to find a balance [innovating and public safety]. How can you have confidence in the robustness of design and how can you still make innovations possible? That requires intensive cooperation in for example Pilot projects." -Interviewee G[3]

One source of uncertainty related to the functioning of the innovation is **unintended side effects**. Unintended side effects are consequences of an innovation that were not intended by the innovator (Sveiby et al., 2018). The impact of these consequences depends on if they are anticipated and desirable. The impact of anticipated consequences can be mitigated by actions ahead of the occurrence of the consequence, the impact of unanticipated consequences cannot. It is not possible to create an all-encompassing list of consequences that are anticipated (Bonifati, 2010; Merton, 1936), and therefore there will always be uncertainty caused by the possibility of unanticipated consequences. When the unintended consequences are desirable, they can still make a big impact but will not hinder the innovation to mature. Unintended consequences that are undesirable will hinder.

[3] All interviewee quotes are translated from Dutch to English with a digital translation service. Interviews took place in Dutch, the native language of participants.

An example of these side effects is when new concrete is developed to have less CO2 emission than the incumbent and the new concrete has the unanticipated consequence that it is also easier to recycle, this makes a big impact on the operations without hindering the innovation to mature. If this new concrete turns out to be heavier than the incumbent, which is an undesirable consequence, this can hinder the innovation to mature.

Another subcategory of functioning is referred to as **the life cycle of the innovation**, how long will it function properly for? Uncertainty about the life cycle expectation and the related costs are of great concern (Interviewee A, C, G). An innovation can be tested for certain aspects and certain periods, however testing the expected life cycle of an innovation is not possible. The expected life cycle of infrastructure should reach into multiple decades, testing for such a period has a high probability that the innovation has become absolute in the meantime. Not knowing the expected lifetime results in, not knowing when to replace or renovate, not knowing what the total costs over a set period will be, and not knowing what the costs of removal will be are all related.

"The innovator has a great idea says and yes it sounds great. But RWS has the responsibility for the infrastructure for the coming 100 years. How do we predict that lifespan? Together we can agree to limit the lifespan or make a test location, like for asfalt" -Interviewee G

"*If it went wrong, that would be after 30 years that this will come to light, it is the risk we saw. We just don't know now. We can monitor, so we can at some point quickly switch if we see something going wrong, but that monitoring costs money and we run the risk that after 30 years we have concrete that is not good and everything should be replaced. Not ideal.*" -Interviewee C

The expected life cycle of an innovation is of importance for RWS because of their current corrective maintenance paradigm (Participant observation 2). Maintenance is currently executed when needed. The uncertainties that come from the life cycle expectation can partly be countered by monitoring the innovation (Interviewee C). In case of a preventive maintenance paradigm, RWS would monitor all the infrastructure as a standard. In the current situation monitoring is thought to be too expensive (Interviewee C).

4.1.2 Development

The development of an innovation is the second type of technological uncertainty experienced in the industry. This uncertainty regards the process of getting from an idea to a usable innovation and is therefore interrelated with the other uncertainties.

It is important that innovation can be **integrated** into the system at RWS. Incompatible RWS-systems can be a source of uncertainty. In one example an innovation was developed using R, when trying to sell it to RWS, it turned out that RWS uses SAS and the innovator was told to rewrite it to SAS (Interviewee M, N, O). Except for the fact that this is a lot of work it could well be that SAS is not capable to run the innovation, or many other technical difficulties. The interviewees were asked if there is a process in place that in these kind of examples evaluates to potential of starting to work with the different system, the answer was no (Interviewee M, N, O).

One interviewee referred to the integration problem as a "Cauliflower effect" in which all innovations are added on the incumbent techniques without integration, making the system look like a cauliflower.

"*So I think you can see in that, it's very easy to add such an innovation, add a little something, or stick it on, but it's very difficult to avoid getting a kind of cauliflower story. With all the great ideas that keep popping up, you know the idea of a cauliflower, so that, it looks a bit lumpy on the outside* *because every time a new idea has popped up, it's no longer a big whole or something*." -Interviewee D

4.1.3 Use

The third subcategory of technological uncertainty is uncertainty related to how the innovation is going to be used.

The first question regarding the use of the innovation regards **who is going to use the innovation**. Private companies in the industry have limited knowledge about how RWS works, it is not clear for them by which RWS employees and departments the innovation is going to be used, consequently it is uncertain how they will use it. Not knowing who can and will use it, will implicate that it is unclear who can and will pay for the innovation as well.

The second uncertainty regarding the use of the innovation is the **user adaption**. Innovating equals changing and that brings uncertainty about if users are willing to change, how long it will take them to adapt, who is responsible for that change, and what the impact of those changes will be. These topics are highly related to the socio/political and management circumstances at the time.

The usability of certain innovations depends on the adaption rate of innovations (Interviewee D, I). An example in which the adaption rate is important and RWS does not have influence over it, is floating car data that could be of high value for RWS, it can however only become of value when enough drivers have bought a car that generates this type of data. The useability of the system was dependent on an uncertain factor.

4.2 Market Uncertainty

According to Gibbons & Littler (1979) market uncertainty is related to; the needs of customers, the reaction of downstream intermediaries, the actions of competitors, and the price development of substitutes. Each of these sources are elaborated in separate sub-sections. In the RWS practice the uncertainties are customer needs related. Figure 7 depicts the subcategories of market uncertainty, the blacklined categories are known from literature but were out of scope for this research.

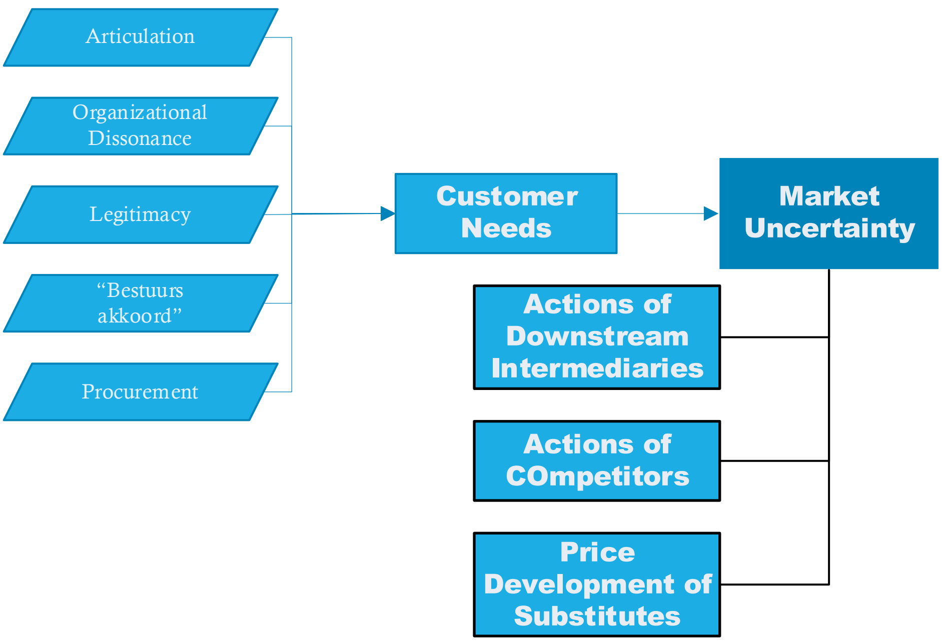

Figure 7: Subcategories of Market Uncertainty. Based on: Interviews and Gibbons & Littler (1979)

4.2.1 Customer needs

MacCormack & Verganti (2003) state that it is uncertain what the needs of the customer are and that those needs are more unclear when the innovation has a higher degree of novelty. Chakravarthy (1985) and Steensma & Fairbank (1999) define that market uncertainty as that it is unknown if the market will want to use the innovation, even when the innovation better fits their needs.

The Dutch parliament is reelected and negotiated every 4 years. It is the sitting parliament that set out the course of directions for the ministries and their organizations in the **"Bestuursakkoord"**. Unknown future election outcomes can change the higher level directions set every 4 years and are therefore a source of uncertainty about the needs of RWS.

Another source of uncertainty is **the way the needs of RWS are articulated**. For outsiders, it is hard to understand how things work at RWS (Interviewees E, K, M, P)). The needs of RWS can be categorized into problem needs and ambition needs (Interviewee G). When a problem arises while working on a project, the project team will work hard to find an innovative solution to fix it. In the case of ambitions set by RWS, such as an emission reduction, the situation is nothing like that of an ad-hoc problem up until the first pilot, as the project where the problem arises will function as the first pilot.

At RWS it is not even sure if they will use the innovation even when the innovation is an answer to a, particularly articulated need. A problem at RWS that is causing uncertainty is **organizational dissonance,** where different units have different goals (Interviewee E, G, M, N, O, T). This mostly has to do with the way **procurement** takes place. An example is that RWS has set goals to become emission-free, but when tenders are put into the market they do not have any emission criteria or way other criteria more heavily (Interviewees E, K, L, P, Q). This could lead to innovators anticipating to those set goals and thus needs, who will consequently never win the tender because their low-emission solution is more expensive.

"*What will the tender team [innovator] do? They want to win that assignment. […]. And then they look really very clearly like: okay this is being asked, so I have to write down so much of this because that gives me points. Well, if innovation is not part of that request and we have little room to write innovations in the plan, yes, because those rules are limited, so to speak, then it won't come easy either. So it is important that it is also asked and therefore also leads to points. Then the tender teams start thinking: oh we have to score points on this. And then they come to me or to other people in [organization] like: gosh we need to have an innovation, help us.*" -Interviewee P

"*We won't get any opportunities to apply it [innovations] in the market, nor they won't prescribe [innovation], nor will they make space in a public tender [for innovation]. And of course we would like that space in a public tender to apply our technology. And look, you can validate a technique, but if you then only want to tender traditionally in your tendering process, then you are not allowing the market to also incorporate innovations*." -Interviewee L

Innovations need to be used by customers for them to be successful, the innovation should be accepted and **legitimate**. Two types of legitimacy can be defined (Aldrich & Fiol, 1994). The user needs a certain knowledge base to use the innovation. When the user has that knowledge the innovation has cognitive legitimacy. The innovation needs to be aligned with the users' world view, norms, and values, then it has sociopolitical legitimacy. The user experiences uncertainty when the innovation is not aligned with its knowledge and worldview. Acceptance will be influenced by the context of the user, its worldview. Knowledge and normative assumptions are what influence peoples' way of reasoning about innovations (Lehoux et al., 2009).

An important question is what ultimately legitimates innovations. “Is it that people will be convinced once the innovation works, or is it that the innovation will work when all relevant people are convinced?” (Jalonen, 2011)

This question can partly be answered by the observation that private organizations innovate proactively and plentifully (exploratory conversations and focus group). There are ulterior motives that drive the private organizations to innovate other than the needs of RWS, such as their own sustainability goals. (Interviewee H, J, K, L, P)

For organizations in the road infrastructure industry, the government is the largest customer. It is therefore that Caerteling et al. (2008) state that the government is of great influence on the viability of the businesses and their products, and that government procurement dominates the diffusion and adaption of the innovations. However, private companies in the infrastructure industry prefer to work with private clients than with public clients because they experience a more dynamic implementation of their innovations. (Interviewee K, L, P)

The government does not want to rely on a single supplier, they support multiple innovations or even similar innovations at multiple suppliers (Caerteling et al., 2008). This impacts the uncertainty with regards to competitors as in the case of a governmental buyer, that is highly concerned with a leveled-playing-field, being the only supplier is not favorable.

4.2.2 Actions of downstream intermediaries

Uncertainty will arise from not knowing what the actions of downstream intermediaries will be (Gibbons & Littler, 1979). In the infrastructure industry, there is a limited number of construction companies that contest for the tenders of RWS, who collaborate with a variety of smaller sub-contractors. Innovations that occur at those sub-contractors are not only relying on RWS as the final client but also on the construction intermediaries that hire them. Complicating the path from invention to commercialization. Uncertainty arises from collaboration with those intermediaries as will be explained below.

4.2.3 Actions of competitors

Uncertainty arises from the lack of knowledge about the actions and intentions of competitors(McDermott & O’Connor, 2002; Naranjo-Gil, 2009). Competitors can be working on different innovations with similar applications or potentially on similar innovations. As noted before in the case of a governmental client it can be important to have competitors work on similar applications as the government cannot engage in procurement of something available at only one (Caerteling et al., 2008).

4.2.4 Price development of substitutes

Uncertainty can arise from not knowing the price development of competing innovations. This uncertainty is minor in scope (Jalonen, 2011) compared to the other sources of market uncertainty and is interrelated as the price of competing innovations is, among other things, based on the intention of the competitor. A competitor can be willing to take losses for a long time to force competitors out of business, for example. As competing innovations can need different raw materials, the price development of those raw materials is also a source of uncertainty (Gibbons & Littler, 1979).

4.3 Management Uncertainty

Jalonen (2011) defines that innovating requires different types of management than pursuing the regular way of working, uncertainty arises from not knowing the effectiveness of those innovation **management activities** and the **lack of metrics to support decision making**. Koen et al. (2010) find that successful innovations require a new and appropriate business model that is oftentimes unlike the **business models** for their widely used offerings. Figure 8 shows the different subcategories of management uncertainty.

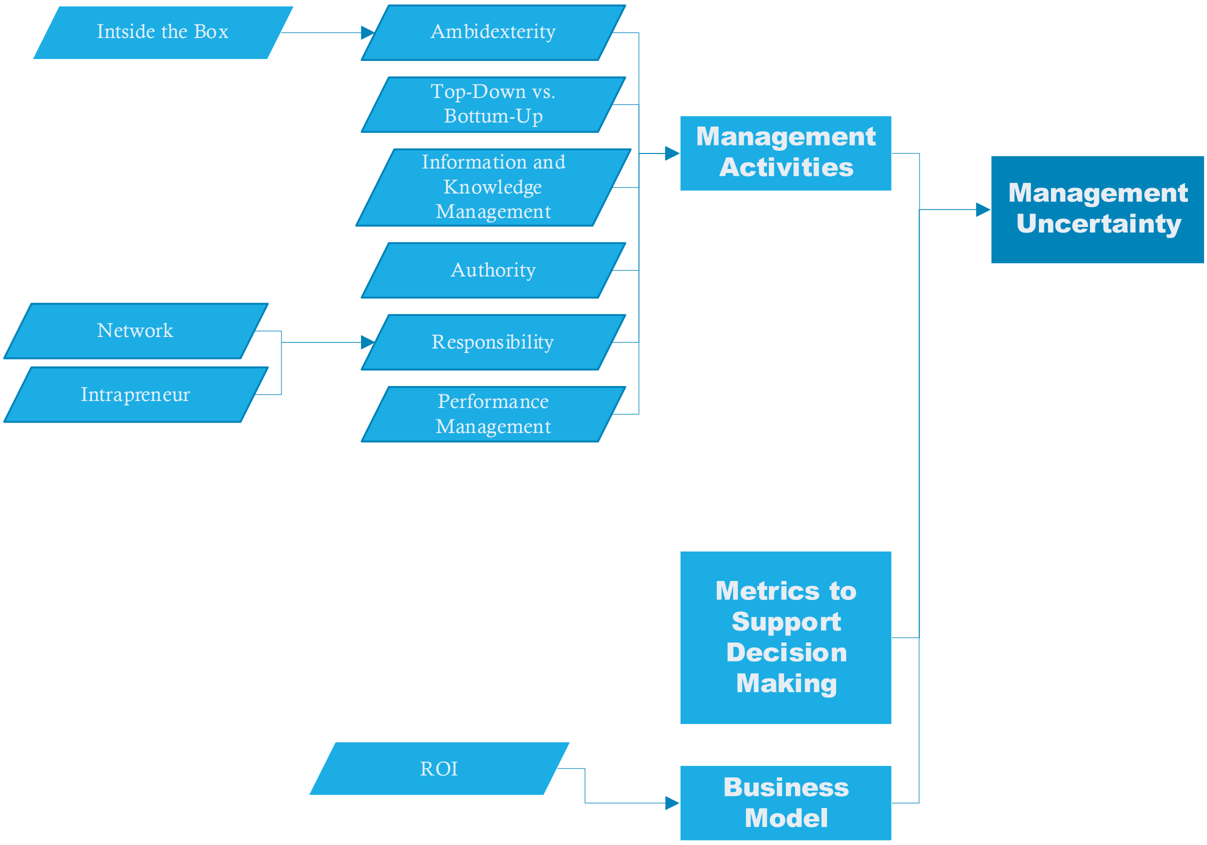

Figure 8: Subcategories of Management Uncertainty. Basesd on interviews and Jalonen (2011); Koen et al. (2010)

4.3.1 Management Activities

Managing innovations is radically different from managing the construction projects or maintenance that are the core of what RWS has always done (Interviewee C, E, G). It is of importance for the future of the nation's infrastructure and the companies in the industry that RWS is **ambidexter**, exploits what they always have been doing well, and explores innovations at the same time (Birkinshaw & Gibson, z.d.; He & Wong, 2004; Lin et al., 2007; Simsek et al., 2009). However, Interviewee P thinks that most projects are incremental and do not represent out-of-the-box thinking.

RWS is a hierarchical organization with multiple management layers and a clear chain of command, when it comes to traditional work and projects, there is a **top-down** culture (Exploratory Conversations). From interviews, observations and exploratory conversations, it appears that often innovation management activities are installed **bottom-up** (Interviewee F, I, M, N, O). This is a conflict that brings uncertainties because lower-level employees struggle to find support from their managers to secure human and financial resources, and there exists a lack of coordination across the different bottom-up initiatives (Interviewee C, I, M, N, O, Observation 2, 3, 4)

Alongside uncertainty about who does what, there is uncertainty about what innovations are currently worked on, have been killed, or are now successfully integrated as a result of a lack of **knowledge and information management** (Grunewald, 2020). In absence of databases and information management systems, good internal communications and relations could be used to inform colleagues (Interviewee A, C, D, E, F, I, Participant observations 2, 3, 4).

The combination of the fact that the exploring activities are done outside the exploitation management structure and that innovation initiatives organized bottom-up causes uncertainty about where the **responsibility** and **authority** lie for innovations. Innovations do not make it into implementation because it is uncertain who has to decide to move the innovation to the next phase or to take on the task of getting it there (Participant observation 1, 2, 3, 4).

Due to this **lack of designated responsibles,** innovators are often dependent on their **network**. For innovators finding the right person within RWS to help the innovator with regulatory issues, tests, or pilot locations depends on who is in their network (Interviewee C, F, H, I, J, K, M, N, O, P and exploratory conversations). Innovations depend on individuals within RWS to succeed. These RWS employees are the **intrapreneurs** that have an entrepreneurial mindset and take on projects or innovations from their intrinsic motivation. (Interviewee B, C, D, E, F, I, Participant observation 1, 2, 3, 4)

A final consideration in exploring versus exploiting is the **performance management** of employees. In Participation observation 1, several employees manifested that it is difficult to become intrapreneurs, as they find multiple cultural and organizational barriers to behave outside of the norm and standard procedures, an issue also interviewee C struggles with.

4.3.2 Metrics to support Decision Making

Another source of uncertainty are the metrics to support decision-making. It is complicated to measure emissions and compare them, for example. An innovation that is currently in the funnel is light reflecting asphalt, using this asphalt in tunnels reduces the use of electricity for lamps. Now some are fully enthusiastic about it, saying this electricity-saving innovation should become the standard, while other question whether this positive effect is not countered by higher molting temperatures, more complicated recycling, or cleaning the machine in between regular and reflecting asphalt (Interviewee C, G). One of the big questions is: How do we know what alternative is more sustainable? Making decisions requires information to base them on, but there is a lack of metrics that support decision-making based on this information. For example, the CIP is struggling with the decision to either focus on the recycling of concrete or alternatives for concrete. The preliminary answer is to focus on both. Innovators would benefit from knowing how and why decisions at RWS are made so that they know which innovations have potential and which do not (Interviewee H, J, Q).

"You have to talk to the stakeholders. These are the initiators, governmental, permitting authorities and marketparties, these are the technicians within Rijkswaterstaat, these are the people from the project team, from the regular project team and people from health and safety" -Interviewee E

"But on the other hand, you mainly try to understand decision processes. And to get a sense of that, how do those considerations come about? And based on that, you as a market party can make a better estimate of what your cards are like." -Interviewee Q

4.3.3 Business Model

Finally, the business model is a source of uncertainty that falls within the category of management uncertainty. It is crucial for the innovator that he makes a return on his investment, the **Return on Investments** made and the Payback Period are two financial indicators used to make investment decisions and to assess the successfulness of an investment that is used by innovators in this study (Berk et al., 2019) (Interviewee P). They experience that in practice it is uncertain when and how much return they are going to make. An important aspect of this is that RWS is a public organization that needs to achieve public value and has a different attitude towards money (Interviewee P, Participant observation 2).

At RWS the maintenance financial circle is 4 years, plans and budgets are made for these 4 years. Not for 4 running years, but 4 set years. This means that investing in an innovation that pays itself back in 8 years is complicated, as RWS only takes into account the years that are in the current financial cycle. For innovators, it is uncertain how to articulate their value proposition in such a way that it matches RWS finance structures. The second source of uncertainty for the business model of the innovator that is caused by RWS management is the corrective maintenance paradigm that RWS works with. If an innovator has an innovation that could prevent downtime and costs by performing preventive measures, there will be high uncertainty on how to incorporate that in the way of working and financing.

Saylor Breckenridge & Taplin (2009) find that managers generally minimize uncertainty by adjusting innovations, minimizing organizational disruption, and unpredictable outcomes that could undermine their position. This behavior can hinder the scaling-up of the original innovation.

4.4 Social Political Uncertainty

Social/ political uncertainty is defined by Jalonen (2011) as uncertainty following the diverse interests of the different people, departments, and organizations that work together. Cantarello et al. (2011) define behavioral [social political] uncertainty as the uncertainty related to cooperation, the risk of opportunism by the partners involved, the trust that has or has not been built over previous transactions, and not knowing how the financial benefits will be divided. Figure 9 shows the different subcategories that are part of social political uncertainty.

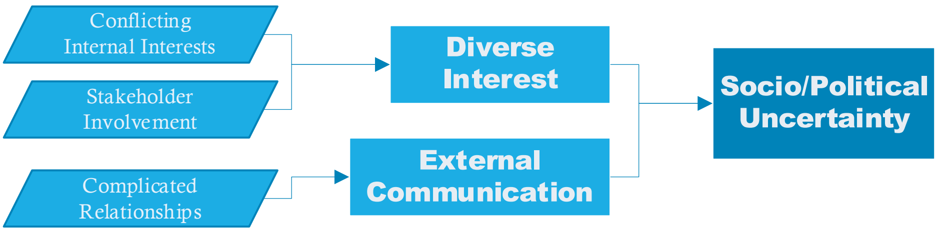

Figure 9: Sub Categories of Social Political Uncertainty. Based on interviews and Cantarello et al. (2011); Jalonen (2011)

4.4.1 Diverse Interests

Not only the interests of the innovator and RWS are different, but the different departments within RWS also each have their own interests. One example of **conflicting interests within RWS** is “the need for making plans and formulating guidelines” vs. “the need for anticipation and freedom” (Interviewee A). The most important difference of interest is that the projects are managed to minimize costs while innovating takes time and requires upfront investments; this conflict is perceived as highly problematic (Interviewee B, C, E, F, G, I, K, P).

An important factor regarding these different interests is **stakeholder involvement**. Omitting to involve certain stakeholders, as well as having certain stakeholder groups extensively involved, both are causing socio/political uncertainty.

“You have to talk to the stakeholders. These are the initiators, these are the technicians within Rijkswaterstaat, these are the people from the project team, from the regular project team, people from health and safety,” -Interviewee F

Often when uncertainty is faced, partners are sought to work together and share those uncertainties with. The problem is that working together itself causes even more uncertainty. Scaling up an innovation requires multiple different parties to work together and so brings uncertainty.

The cooperation between a private organization and RWS is an example of a situation where this type of uncertainty can arise, even though the cooperation is started to reduce the other forms of uncertainty. Innovations can also require multiple private organizations working together, with all of the collaborators as a source of uncertainty.

4.4.2 External Communication

Koch (2004) finds that external communication is key to secure the recourses needed for successful innovations and that building a coalition that supports the innovation is of importance to ensure a smooth innovation process. The power of individuals and their diverse interests are an important influence on these coalitions and recourses.

Interviews with industry representatives suggest they are not aware of the existence of the Innovation Loket and other innovation activities at RWS (Interviewee H, J, K, L, P, Q), while RWS employees are under the assumption that "the innovators know", and that all the information present in their websites and publications are read (Interviewee A, E, F, M, N, O, and exploratory conversations). Interviewee E indicated that innovators from the industry participate in creating roadmaps for certain innovation areas. However, the innovators that participated in this study stress out that communication between them and RWS is problematic for their innovation process, and that they are not aware of such activities (Interviewee H, J, K, P, Q)..

"*And maybe the organizations should come closer to each other and get out of the client-contractor cramp a bit*." -Interviewee P

4.5 Regulatory Uncertainty

The fifth source of uncertainty is regulation. Regulations can be enabling, like intellectual property protection. In the infrastructure industry, innovations are impeded by the different contract forms that require innovators to transfer the ownership of their intellectual property to RWS (McKinsey & Company, 2019). Only DBFM contracts allow the innovator to preserve ownership. Regulation can be restraining, as when innovations in the industry have to adhere to certain regulations. Especially when those regulations are not fit (anymore) to assess innovations (McKinsey & Company, 2019).

Hoffmann et al. (2009) find that in cases of high regulatory uncertainty investments in innovations might hold off, and form propositions about what motivates companies to invest despite those uncertainties. Companies that perceive a high level of regulatory uncertainty do not postpone investment decisions if these decisions secure competitive resources, leverage complementary resources, or alleviate institutional pressure. Regulatory uncertainty negatively affects the quantity, quality, originality, and riskiness of the innovation activities (Bhattacharya et al., 2017).

The infrastructure industry is influenced by regulatory uncertainty to a high extend. The infrastructure is a public good that must be safe for all users for a long time. The focus of regulators is to ensure safety and not to adopt new technologies. The problem with the legislation is that changing it often has high lead times and is under the influence of periodically changing representatives of the people.

Although regulations themselves can be enabling for innovations, the regulatory uncertainty is a restricting factor. Bonnin Roca & O'Sullivan (2020) define three types of regulatory uncertainty. The first being rule content uncertainty, regarding the possibility that regulations might change, in combination with the unknown impact of those changes. Secondly, final compliance uncertainty is caused by the inability to know if the innovation will comply with the regulations. The final type of regulatory uncertainty, qualification method, regards expensive qualification methods or unfit rules to assess the innovation. Figure 10 depicts the different subcategories of regulatory uncertainty.

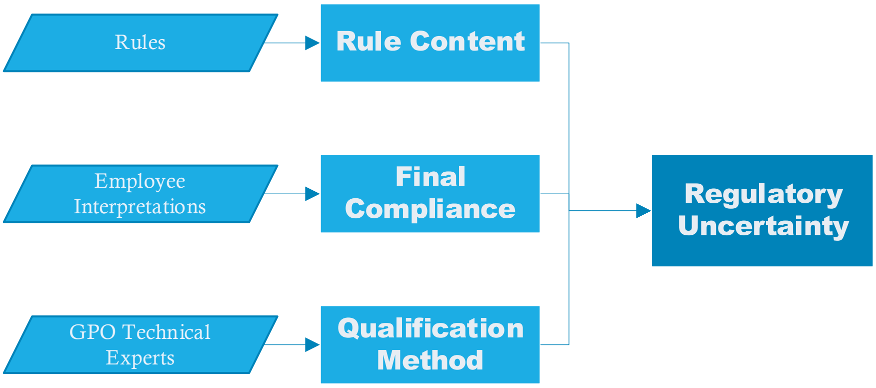

Figure 10: Sub Categories of Regulatory Uncertainty. Based on interviews and Bhattacharya et al. (2017); Bonnin Roca & O'Sullivan (2020); Hoffmann et al. (2009); McKinsey & Company (2019)

4.5.1 Rule Content

An example of an innovation that is not used by RWS because of rule content uncertainty is the newly developed detection loop, a system to detect the presence of cars on a road (Interviewee P). This loop can be used in roads to collect data and differs from incumbent loops in the application to the road. For incumbent loops, the asphalt needs to be cut open so that the loops can be placed into those cuts. The new loops could just be put on the base layer and then covered with asphalt during the road construction, reducing labor and ensuring a smoother road. The innovative loops are currently not in use because regulation prescribes the way loops need to be cut into the asphalt, a **rule** the innovative loops cannot comply with.

4.5.2 Final Compliance

Final compliance uncertainty plays an important role in the behavior of RWS employees. Examples of regulations that are important regard the leveled-playing-field and state aid, different employees have different interpretations of these regulations and take actions accordingly. These different interpretations are a source of uncertainty, the innovation's success can be influenced by how the involved employees perceive the regulations. (Interviewee B, C, E, F, P)

4.5.3 Qualification Method

There are lists with regulations and accepted technologies with which an innovator can prove to comply or an innovator can request additions or changes (Interviewee A). In either way the decision is taken by **GPO Technical Experts**, or researchers from universities or research facilities. The experts assess the situation of the innovation and set the minimum requirements that the test results have to meet for changes or additions. When the requirements are met, the GPO Technical Experts have the authority to make changes and additions. To proof the compliance with the requirements, the innovator has to find a test location. For asphalt the Innovation Test Centre might help, for all other innovations the innovator is reliant on a willing intrapreneur in their own network. The same structure holds for finding the right GPO Technical Expert. It becomes more difficult when innovations are not inside the RWS boxes of concrete or steal, which expert then has to be involved, which expert has authority (Interviewee P)? For digital innovations, no such process is in place (Interviewee D, H, J, M, N, O).

4.6 Time Uncertainty

Sixth, Jalonen (2011) finds uncertainty related to time, these uncertainties can be related to the complexity of time, the interconnectedness of time, the lead times in the industry or timing. Figure 11 depicts the different subcategories of uncertainty related to time.

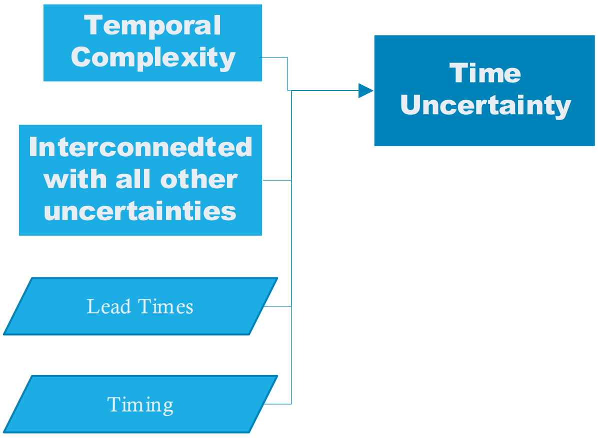

Figure 11: Sub Categories of Time Uncertainty

An important concept is **temporal complexity** defined by Halbesleben et al. (2003), indicating that everyone has a different perception of time and that time can be seen as a social construct. Figure 12 shows a visualization of the concept of temporal complexity.

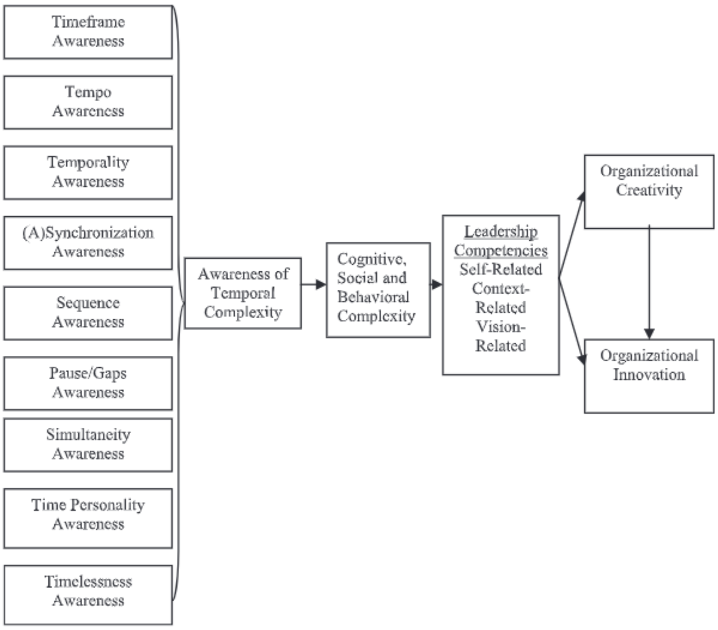

Figure 12 Temporal Complexity (Halbesleben et al., 2003)

Other uncertainties can be connected to time uncertainties. During the innovation process, more knowledge will become available, but oftentimes decisions have to be made in earlier stages when different uncertainties are still high. The question then becomes when to make decisions, as postponing decisions will increase the lead time. As time passes and innovations mature, more cooperation will take place and that brings more uncertainty. A reoccurring question with a big impact regards the life cycle of the innovation; how long will it function for? Testing certain materials to estimate their total lifetime expectation can take years, years that affect the lead time.

In the road infrastructure industry, the **lead times** are relatively long in comparison to other industries. The scaling-up of innovations in this industry can take years. The perception of time in the industry is aligned with those lead times, decision-makers will take time, as fast decisions are not making a difference on the total lead time. When an innovation has been under development for 10 years, another day of debate among decision-makers will not make an impact. The lead time is highly related to technological uncertainty, uncertainty about the development of in the innovation makes the lead time uncertain, uncertainty about the functioning of the innovation makes that people want to do more tests and thus makes the lead time more uncertain, and uncertainty about who is going to use the innovation and how is also enlarging the lead time.

The final construct of time uncertainty is **timing**. If an innovator wants to test or pilot its innovation he must find a project that is in a project phase where this is still possible. This means that on top of using his network to find an intrapreneur who is willing to take on the innovation he needs to find an intrapreneur who is in the right phase of a project. This is where MIRT, the project planning approach used at RWS, has to be taken into account. Another uncertainty related to timing is the question of when to enter the market with the innovation. Timing-related problems are cannibalization (Macdonald & Jinliang, 1994) and the window of opportunity for entry (Suarez et al., 2015).

4.7 Conclusion

This chapter answers SQ1: What are the main uncertainties that affect the upscaling and commercialization of innovations? The 6 categories of uncertainty and the subcategories that affect innovations in their maturation are presented in table 2. This classification of uncertainties will be used to structure the findings of the following chapters with, these uncertainties are the backbone of the further findings.

Tabel 2: An Overview of the Different Uncertainty Categories

Uncertainty Category	Subcategories
Technological	Functioning Development Use
Market	Customer Needs
Management	Management Activities Metrics to Support Decision Making Business Model
Social/Political	Diverse Interest External Communication
Regulatory	Rule Content Final Compliance Qualification Method
Time	Temporal Complexity Interconnectedness of Time Lead Times Timing

5 Public Organizations and Public Policy

The second research question concerns the possible innovation policies that RWS could implement to mitigate the in chapter 4 defined uncertainties. This chapter will give an overview of what public policy is and what types of public policy could be defined. These policies could be implemented by RWS.

Innovation policy is the set of actions taken by public organizations, such as RWS, to influence innovation processes (Mazzucato, 2017). Innovation policy is what RWS has within their ability to use in order to influence the innovation in the industry. This chapter will illustrate some of the policy instruments that RWS can use to solve the problem at hand, first, however, public policy as a concept will be introduced.

Edquist (2011) specifies two requirements for public intervention in the market, the first being that private organizations must prove to be unwilling or unsuccessful in achieving the objectives, and secondly the public organizations must have the ability the solve that.

Schot & Steinmueller (2018) made an overview of the history of innovation policy and find that there have been different views on innovation policy. Innovation policy started after the second world war with a focus on economic growth in which there was a lot of R&D funding. In the 1980s innovation policy started to focus more on learning between the actors of an innovation system, still with the aim of economic growth. All that time it was about fixing, first fixing the market and later about fixing the system. Around the start of the 21st century, the realization came that innovation policy could be aligned with solving big challenges such as climate change or social injustices (Schot & Steinmueller, 2018). From then on the aim was beyond fixing, it is about transforming, about creating and shaping the market. The big challenges society is facing can be translated into missions, with the result of mission-oriented innovation.

A mission addresses a societal demand, creates a long-term public agenda, should be feasible, and have broad political support (Edquist & Zabala-Iturriagagoitia, 2012). The mission and subsequent goals of RWS can be found in chapter 1. The innovation policy instruments that RWS currently uses or will use in the future, should all have the purpose of achieving the in chapter 1 defined mission and goals and intent to stimulate innovations that contribute to them (Borrás & Edquist, 2013).

What the right type of policy is depends heavily on the specific innovation and its context, for example, the market, location, and time (Edler, 2016). Every innovation policy instrument is unique because it has to be tailored to the specific needs of the situation (Borrás & Edquist, 2013). The best policy is always a mix of different policies fitted to the specific context (Borrás & Edquist, 2013; Edler, 2016; Hellsmark et al., 2016). To create effective innovation policy it is necessary to understand the problem that the policy needs to fix (Borrás & Edquist, 2013). Chapter 4 describes the different uncertainties that could be a barrier to the maturation of innovations, the aim of the innovation policies that RWS will implement intent to mitigate these uncertainties, which are the problem of interest in this research. The choice of policy instruments has three important dimensions: *"Firstly, a primary selection of the specific instruments most suitable among the wide range of different possible instruments; secondly, the concrete design and/or 'customization' of the instruments for the context in which they are supposed to operate; and thirdly, the design of an instrument mix, or set of different and complementary policy instruments, to address the problems identified."* (Borrás & Edquist, 2013)

Like for every other product, there is a market consisting of supply and demand for innovations. In the case of the infrastructure industry, there is supply from the innovators and demand from the government, specifically RWS, and, to a less extend, provinces and municipalities. When innovation policy is installed, the policy can either be affecting the demand for the innovation or the available supply (Edler & Georghiou, 2007). Supply and demand are interconnected and, in the long run, affect each other. The innovation policy types summarized from the literature for this thesis are all interrelate with each other, the final recommended strategy will consist of multiple types of policy mixed together. RWS is the implementing organization of the ministry, and public procurement is one of the key processes it undertakes. Both demand and supply-side innovation policy can be implemented by RWS. Demand-side innovation policies are directly related to the core tasks of RWS and will be implemented in the standard work processes. Supply-side innovation policies are implemented outside the standard work processes, in national and specifically dedicated teams, programs, and projects.

This chapter presents an overview of innovation policies effective to mitigate the in chapter 4 defined uncertainties. The overview is derived from literature and consists of generic possibilities, not a to RWS tailored prescription, the tailored prescription will follow in chapter 8. The different innovation policies are categorized based on what side of the market they affect.

5.1 Demand Side Innovation Policies

Demand-side innovation policy encompasses all the governmental efforts to increase the demand, to articulating demand, and to define new functional requirements (Edler & Georghiou, 2007). Demand side innovation policies are of significant importance (Geroski, 1990; Palmberg, 2004; Rothwell & Zegveld, 1981; Saarinen, 2005). Four forms of demand-side measures can be defined (Edler & Georghiou, 2007): Systemic policies, Regulations, Public procurement, and Support of private demand.

5.1.1 Systemic policies

Innovation systems have four structural dimensions that together form a system: Actors, Institutions, Infrastructure and Interactions (Wieczorek & Hekkert, 2012). Table 3 clarifies what kind of subcategories are part of these four main dimensions. The innovation system cannot function, if there is a problem with any of these aspects (Carlsson et al., 2002). Systemic problems can be related to the presence as well as to the properties of these elements (Wieczorek & Hekkert, 2012) and negatively influence the speed and direction of innovation processes and systems (Klein Woolthuis et al., 2005).

Tabel 3: Structural Dimensions of a System (Adapted from: (Wieczorek & Hekkert, 2012))

Structural Dimensions	Subcategories
Actors	Civil Society Companies Knowledge Institutes Government NGOs Other
Institutions	Hard: Rules, Laws, Regulations, Instructions Soft: Customs, Habits, Routines, Established Practices, Traditions, Ways of Conduct, Norms, Expectations
Interactions	At Network Level At Individual Contacts Level
Infrastructure	Physical Knowledge Financial

Innovating is an action that is not done by a single organization, often an entire system of innovators is involved in the process. Systemic innovation policy is policy directed at the entire system and not just individual innovators. Smits & Kuhlmann (2004) define 5 purposes of systemic policies:

1. Manage interfaces, so that system participants can interact.
2. Build and organize innovation systems, examples of activities in this category are facilitating prime movers and ensuring all relevant actors are involved.
3. Provide a platform for learning and experimenting.
4. Provide an infrastructure for strategic alliances.
5. Stimulate that demand is articulated and strategies and visions are developed.

Wieczorek & Hekkert (2012) follow up on these findings by Smits & Kuhlmann (2004) and argue that the systemic goals should be coupled to the problems arising in the system. Table 4 gives an overview of the goals defined by Wieczorek & Hekkert (2012) and examples that contribute to those goals.

Individual innovation policy instruments cannot strictly be classified as systemic or not, what makes them systemic is the way in which they are combined to address problems in the innovation system (Borrás & Edquist, 2013). It is therefore that this type of policy does not mitigate one type of uncertainty particularly.

Table 4: Goals of systemic instruments and examples of instruments that contribute to them (Wieczorek & Hekkert, 2012)

Systemic Innovation Policy Goals	Examples of systemic instruments
1. Stimulate and organize participation of actors	Clusters; new forms of Public-Private Partnerships, interactive stakeholder involvement techniques; public debates; scientific workshops; thematic meetings; transition arenas; venture capital; risk capital
2. Create space for actors' capability development	Articulation discourse; backcasting; foresight; road-mapping; brainstorming; education and training programs; technology platforms; scenario development workshops; policy labs; pilot projects
3. Stimulate occurrence of interactions	Cooperative research programs; consensus development conferences; cooperative grants and programs; bridging instruments (centers of excellence, competence centers); collaboration and mobility schemes; policy evaluation procedures; debates facilitating decision-making; science shops; technology transfer
4. Prevent too strong and too weak ties	Timely procurement (strategic, public, R&D-friendly); demonstration centers; strategic niche management; political tools (awards and honors for innovation novelties); loans/guarantees/tax incentives for innovative projects or new technological applications; prizes; Constructive Technology

	Assessment; technology promotion programs; debates, discourses, venture capital; risk capital
5. Secure presence of (hard and soft) institutions	Awareness building measures; information and education campaigns; public debates; lobbying, voluntary labels; voluntary agreements
6. Prevent too weak/stringent institutions	Regulations (public, private); limits; obligations; norms (product, user); agreements; patent laws; standards; taxes; rights; principles; non-compliance mechanisms
7. Stimulate physical, financial, and knowledge infrastructure	Classical R&D grants, taxes, loans, schemes; funds (institutional, investment, guarantee, R&D), subsidies; public research labs
8. Ensure adequate quality of infrastructure	Foresights; trend studies; roadmaps; intelligent benchmarking; SWOT (strengths, weaknesses, opportunities, and threats) analyses; sector and cluster studies; problem/needs/stakeholders/solution analyses; information systems (for program management or project monitoring); evaluation practices and toolkits; user surveys; databases; consultancy services; tailor-made applications of group decision support systems; knowledge management techniques; Technology Assessments; knowledge transfer mechanisms; policy intelligence tools (policy monitoring and evaluation tools, systems analyses); scoreboards; trend charts

The in table 4 defined policy goals and examples match to the different kind of problems that specific systemic dimensions can encounter. Table 5 Matches the systemic dimension, problem, and solutions directions.

Table 5: Matching Systemic Problems with Policy Goals (Adapted from (Wieczorek & Hekkert, 2012))

Systemic Dimension	Problem	Table 2 Policy Goal
Actors	Presence	1
Actors	Capabilities	2
Interaction	Presence	3
Interaction	Capabilities	4
Institutional	Presence	5
Institutional	Capabilities	6
Infrastructural	Presence	7
Infrastructural	Capabilities	8

5.1.2 Regulations

Regulators have to balance the public value created by an innovation with its safety (and other factors) while faced with different kinds of uncertainty (Mandel, 2009). A challenge is to create regulation that fits the characteristics of innovations while dealing with different levels of knowledge and competencies in the industry (Bonnín Roca et al., 2017). A proposed mechanism for balancing this challenge has arisen in the literature under different names, with the same underlying intention to be more flexible, knowledgeable, and coordinate between scientist and private organizations (Bonnín Roca et al., 2017; Guston, 2014; Kuhlmann et al., 2019; McCray et al., 2010).

One approach to regulation could be to develop regulations depending on the level of technological uncertainty present (Bonnín Roca et al., 2017). In which performance-based regulations are used for more mature innovations, management-based regulations for front runners in immature innovations, and technology-based regulations for laggards in immature innovations. Other factors that influence the regulation type are the industry structure, the innovation's impact on human safety, and the relative technological uncertainty. When it comes to the industry structure, a more concentrated structure would benefit from more management-based regulations and a more disaggregated structure would benefit more from technology-based regulation. When it is critical that innovations are safe, it can be better to move to performance-based regulation later than when there are fewer safety issues. If the technological uncertainty is relatively high, it is advised to have a higher level of regulatory discretion.

Another important approach to reducing regulatory uncertainty is to create communication channels with the private organizations in the industry. The information can float in both directions, private organizations share their state of the art knowledge with regulators that do not have industry-specific knowledge so that regulations can be fitted to developments proactively (Link & Metcalfe, 2008; McCray et al., 2010; Petersen & Bloemen, 2015) and the private organizations stay up to date about the current regulations and plans for future changes (Bonnin Roca & O'Sullivan, 2020). Staying up to date about the details of current and future regulations mitigates rule content uncertainty. Regulators responding to state-of-the-art knowledge from the industry ensures that the right rules and qualification processes can be in place to reduce qualification method uncertainty.

Regulators could reduce regulatory uncertainty by signaling the possibilities of future regulations through supporting innovation in the early stages (Bonnin Roca & O'Sullivan, 2020). If new innovations are supported by the government, incumbents can interpret that support as a signal of the direction the government wants to move in. Making credible commitments towards future regulation changes can help innovators anticipate regulations that align with those commitments (Bergek et al., 2008; North & Weingast, 1989).

A final possibility to reduce regulatory uncertainty is to provide clear and structured information on how products can comply with regulations, such as assessment models and simulation tools (Bonnin Roca & O'Sullivan, 2020). Through those services, innovators can detect reasons for failure earlier in the innovation process and in that way final compliance uncertainty can be reduced.

5.1.3 Public Procurement

When Public Procurement is used to trigger innovation that is called Pubic Procurement for Innovation (PPI) (Edler & Georghiou, 2007). PPI can be classified along two dimensions (Edquist & Zabala-Iturriagagoitia, 2012). The **first** dimension is the end-user, Direct PPI is when the public organization is going to use the innovation their selves and Catalytic PPI is when the innovation is going to be used by the wide public. The **second** dimension is the newness of the innovation. In adaptive PPI incremental innovation, only new to the country or region is procured, In developmental PPI the procurement process results in a new-to-the-world innovation. A third, category in this dimension is pre-commercial procurement, in which the procurer purchases R&D.

Edler & Georghiou (2007) give three arguments in favor of PPI:

(1) Demand is an important factor in the attractiveness of a location to settle for companies (Porter, 2014). Early users of a product take the risk of working with a not yet fully optimized product to solve a problem quickly or to stay ahead of the competition. When a single user as a public organization has a lot of purchasing power it can even function as a lead market on its own.

(2) Market imperfections are an important reason for governments to intervene in the market. Organizations are often not aware of what could be offered to them and the other way around, suppliers don't know the customer's needs as an example. All market imperfections entail uncertainty for suppliers.

(3) Based on perceived social needs governments make policies and goals (sustainability goals for example) and innovations that help achieve those goals are worth a premium for the goal-setter. Jalonen (2011) addresses a lack of research in the interaction between achieving those social goals and achieving goals on fostering innovation.

Public procurement may legitimize innovations (Uyarra et al., 2020) as the governmental example can spread the knowledge to create cognitive legitimization and can shape the worldview to create sociopolitical legitimacy and in that way reduce market uncertainty.

When using public procurement, it is important to assess the readiness of the technology to be (pre-commercially) procured. When procurement sets in too early this can be detrimental for the diffusion of the innovation (Edler & Georghiou, 2007).

Interactive learning between organizations is an important predecessor for innovation and from that perspective, it is advised for procurers to work together with potential suppliers starting early on in the PPI process. Edler & Georghiou (2007) advise having focus groups early in the PPI process that involve policymakers, politicians, scientists from all kinds of disciplines, R&D, Marketing, management, and any others that could be relevant. This has to be organized in line with what is allowed by European and local laws.

Table 6 shows an overview of multiple strategies public organizations can use in public procurement. The government can act as a purchaser, lead user, catalyst, or broker (Uyarra et al., 2020).

Table 6: Different government strategies for public procurement (Adapted from Uyarra et al., 2020)

	Solution unclear or contested	Consensus about solutions
Demand poorly articulated or fragmented	**Government as a purchaser of R&D** *Goal*: Increase R&D *Procuerement mode*: PCP *Mitigates*: Technological Uncertainty, Market Uncertainty	**Government as catalyst** *Goal*: Market Creation *Procurement Mode*: Catalytic PPI *Mitigates*: Market Uncertainty
Identified and agreed upon needs	**Government as a lead user** *Goal*: Boost Innovation Procurement mode: Direct PPI *Mitigates*: Market Uncertainty	**Government as broker** *Goal*: Innovation Diffusion Procurement mode: Innovation friendly procurement *Mitigates*: Market Uncertainty

5.1.3.1 The government as a purchaser of R&D

When both the societal problem and potential solution are unclear a special form of PPI, called pre-commercial procurement, is advised. Pre-Commercial Procurement is procurement for products/services for which more R&D is needed and the procurer and potential supplier share the technological risk (Edler & Georghiou, 2007). This type of PPI can be seen as a service contract, the more novel the innovation is, the easier it is to engage in this kind of service contract. When the outcome can be used for more parties than the procurer involved and the procurer is not paying for all of the resources used, it can be that European Directives and the WTO General Procurement Act do not apply (Bos & Corvers, 2007). Public procurers should however make sure that they prevent market imperfections like monopolies and involve multiple competitors in field-testing phase. Aschhoff & Sofka(2009) find empirical proof for the effectiveness of pre-commercial public procurement and specify that it might be specifically helpful for small firms with limited recourses.

Pre-Commercial Procurement reduces market uncertainty because a certain amount of sales is agreed upon while still in the development phase (Aschhoff & Sofka, 2009). Due to the significant scale of the government procurement cost reductions can be implemented early on. The government partly takes on the technological uncertainty, as in the phase the contract is signed in it is still (partly) unknown if the innovation will work as intended.

For pre-commercial procurement to work tenders should be transparent, limited in size, and easily accessible, have short and clear application processes, known by all potential candidates (Uyarra et al., 2020).

In PPI it is important that the technical characteristics given are limited, as they limit the ability and creativity of potential suppliers. Only functional requirements that satisfy the public needs or solve social-cultural problems should be specified (Edler & Georghiou, 2007).

5.1.3.2 The government as lead user

When the societal problem is well articulated and widely agreed on, but there is no clear solution available, the government can act as a lead user. Lead users are users whose present strong needs will become general in the future and can therefore serve as need-forecasters (Beise & Cleff, 2004; von Hippel, 1986). When a single user has sufficient purchasing power, such as RWS, this user can constitute an entire lead market. It is critical for RWS to communicate clear needs by using performance specifications, to foster innovative solutions for those needs (Uyarra et al., 2020). In this way, the government signals the existence of potential users and their belief in the viability (Bleda & Chicot, 2020).

5.1.3.3 The government as a catalyst

In case of a poorly articulated problem but a consensus about the possible solution space, the government can act as a catalyst. Catalytic procurement is when the state is involved with the procurement, but the procured is exclusively used by the private end-user (Edquist & Hommen, 1998). This type of policy aims to support the development of innovation for broad public use (Edquist & Zabala-Iturriagagoitia, 2012). Using this procurement strategy, it is important to align regulation policy to ensure the maturation of the innovation (Uyarra et al., 2020).

5.1.3.4 The government as a broker

When both societal problems and technological solutions may be defined clearly, the government can then act as an innovation broker. As a broker, the government provides operational coordination (Bleda & Chicot, 2020) and focuses on the acquisition, diffusion, and assimilation of existing incremental (Moodysson et al., 2017) innovations (Chiang, 1991). The broker connects the economic strengths with the global demand (Wang, 2015).

5.1.4 Support of Private demand

Demand-side policy includes support of private demand in the industry. In the case of RWS, this should be viewed broader than private demand, there is no private demand for bridges or highways, there are, however, provinces and municipalities that innovations can spill over to. Although there might not be private demand for a highway, there might be private demand for the specific innovative materials or techniques used in the infrastructure. An example is 3D concrete printing that can be used for both bridges (public) and real estate (private). Examples of these policies can be financial in the form of subsidies and tax incentives (Edler, 2016), which are not in the scope of RWS. Examples of indirect policies are awareness building and informing (Edler, 2016), which can be done by RWS, by for example sharing their experiences with innovations proactively with the public.

5.2 Supply-Side Innovation Policy

Although less obvious from the RWS perspective, supply-side innovation policy is of great value for the development of innovations and fits the scope of RWS equally as the demand-side policies. Plenty of supply-side innovation policy instruments are available (Edler & Georghiou, 2007). R&D subsidies are perhaps the most widely used supply-side innovation policy instrument and another traditional policy instrument on the supply side is providing the structure for research at Universities and other public research centers (Aschhoff & Sofka, 2009; Geroski, 1990; Rothwell & Zegveld, 1981). One supply-side instrument that is currently actively used by RWS is pilot and demonstration plants.

5.2.1 R&D Subsidies

R&D subsidies support public organizations in their financial needs for creating innovations. This policy instrument is used for the research and development of innovations with a high social return (Aschhoff & Sofka, 2009).

5.2.2 Universities and Public Research

Facilitating and promoting Public Research is a supply-side measure that increases the number of innovations that become available. This instrument does not provide direct financial support for businesses, but is indirect and provides the infrastructure needed for basic research (Aschhoff & Sofka, 2009; Rothwell & Zegveld, 1981). This fundamental research expands the capabilities of the economy to generate new innovations (Geroski, 1990) and mitigates technological uncertainty because it has a positive impact on the knowledge base (Rothwell & Zegveld, 1981). The knowledge generated from these activities is then widely available to all private organizations who want to use it. To ensure that this knowledge can and is used collaboration between those researchers, the private organizations in the industry, and governmental organizations is required (Aschhoff & Sofka, 2009; Caloghirou et al., 2001).

RWS can use this policy instrument in two different ways. Firstly, RWS can provide the infrastructure needed for research by providing information, problems, and research positions for example. Secondly, RWS can facilitate the collaboration between the researchers, industry, and themselves.

5.2.3 Pilot and Demonstration Plants (PDP)

PDPs are pilot and demonstration plants that can serve as more advanced testing facilities than initial labs. The test can take place in a situation as close to real-life as possible. PDPs are crucial for advancing new knowledge (Hellsmark et al., 2016). “A demonstration project is defined as a finite initiative to test a technology according to the project objectives.”(Karlström & Sandén, 2004)

PDPs have been of interest for multiple literature streams, in which the key ideas about PDPs have been slightly different. Where engineers and natural scientist mainly view PDPs as a tool for up-scaling and verification technologies, do technology and innovation managers have a slightly broader view seeing PDPs as tools for product and process design and up-scaling, innovation systems literature considers PDPs useful for developing the socio-technical system as well (Frishammar et al., 2015).

PDPs assist in advancing technologies towards industrial-scale production and socio-technical systems, it helps to align the new technologies with regulations, by which regulatory uncertainty can be mitigated. PDPs are crucial to create socio-technical systems around the new technologies and help to establish a new market, and form public attitudes, in which they can mitigate market uncertainty. They contribute to learning processes, reduce uncertainties and help the innovations to scale-up. Table 7 shows the different types of DPDs and the roles they can play in the innovation process (Hellsmark et al., 2016), as well as how those types of DPDs mitigate uncertainties. Figure 13 shows the effect of the different types of DPDs on the maturity process. Figure 14 shows another classification of PDPs, in this classification Science, Technology, Application, and Market are used to indicate the maturity of the concept, the darker color PDPs are considered the responsibility of the scientist and the lighter color PDPs are in the domain of the designer (Moultrie, 2015).

Table 7: Types of PDP's their roles and reduced uncertainties (Adapted from Hellsmark et al., 2016)

Type of PDP	Role of the PDP	Uncertainty Reduction
High profile PDPs.	Creating awareness and legitimacy by an actor with clear commercial interests in a specific application, thereby influencing and receiving feedback from potential customers and policy on new technology, product, process, or service.	Do not reduce technical risks in any real sense, but may reduce market and institutional risks indirectly
Lab-scale verification PDPs.	Testing, evaluating, and characterizing a technology for a particular application, reducing mainly technical risk for potential stakeholders by creating new scientific and practical knowledge that can be applied at a larger PDP scale or in a commercial setting	Mainly reduces technical uncertainty by expanding scientific knowledgebase.
Industrial-scale verification PDPs.	Creating new knowledge, verifying technology by constructing a reference plant at a large but not necessarily optimal scale for a specific application, thereby creating an industrial capacity among technology suppliers and their potential customers.	Important for reducing market and organizational uncertainties, but also technical uncertainty.
Deployment PDPs.	Improving performance and reducing costs by accumulating operational experience, stimulating incremental innovation, and increasing efficiency along value chains as well as getting access to users' know-how and experiences.	Important for reducing market and organizational uncertainties, but also technical uncertainty.

Market introduction of down- and up-stream auxiliary technologies.	Creating and testing different value chains in practice, reducing the product and organizational risks, creating public acceptance, mobilizing further resources to the field, and addressing institutional risks by developing new standards and stimulating the introduction of new regulations, thereby paving the way for investments in deployment PDPs.	Reducing the product and organizational uncertainty as value chains are formed, tested, and evaluated.
Permanent test centers.	Serving a wide set of industrial actors and academia to make continuous improvements, testing new technological options, thus facilitating basic and applied research. These target a wider set of different applications and purposes than the other types of plants.	Mainly reduces the technical uncertainty involved in making the development of new technological options possible.

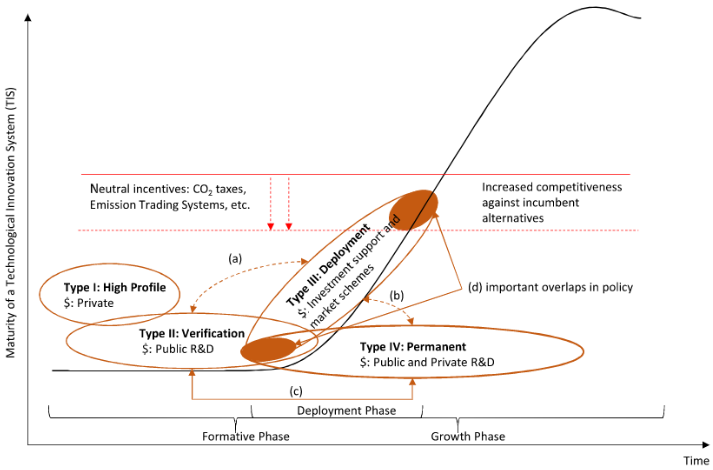

Fig. 1. PDPs and the Development of a Technological Field, the Role of Innovation Policy.

Figure 13: The influence of different types of DPDs on the innovation maturity (Hellsmark et al., 2016)

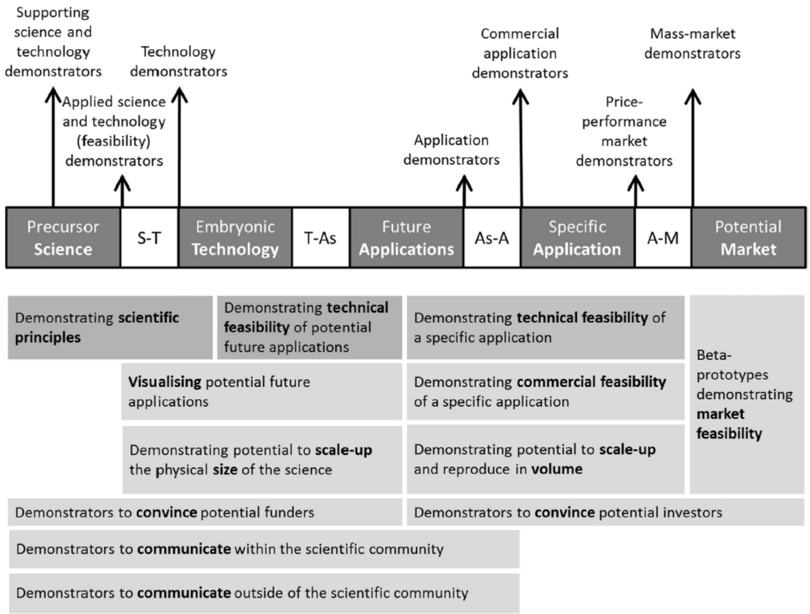

Figure 14: PDP Categories (Moultrie, 2015)

5.3 Conclusion

This chapter has introduced the concept of public policy. Innovation policy, policy directed at fostering innovations in the market can take many forms. The general classification of innovation policies is in policies that affect the demand for innovations and policies that affect the supply of innovations. Within demand side policies there are systemic policies, regulations, and public procurement. Supply side policies are R&D subsidies, supporting universities and private research, and pilot and demonstration plants. An optimal policy mix has to be tailored to the situation at hand.

6 RWS Procedures to Mitigate Uncertainty

RWS has numerous intrapreneurs such as interviewee B, C, D, F, G, I, M, N, O and participants from observation 1, 2, 3, 4 and a variety of innovation initiatives. These intrapreneurs are all devoted to either a specific innovation, putting efforts to mature it, or to innovation in general, some of them reduce uncertainty, intendedly or unintendedly. Next to those initiatives from intrapreneurs, there are more set departments, programs and other bodies that, intentionally or not, mitigate uncertainty during innovation. This chapter lists all the procedures that are currently in place at RWS to mitigate uncertainties and answers SQ3: *What procedures are in place at RWS to mitigate the in SQ1 defined uncertainties?* In order to represent these procedures in place at RWS to mitigate uncertainties, they are represented in relation to the situation in which they are used. Table 8 presents the final overview of all the procedures in place.

There are three main situations that can occur, a technology can be pushed by the innovator, RWS (the market in this case) can pull for innovations, and a special combination, for convenience, called push-pull. This is a situation observed in practice in which certain departments of RWS, that are not involved with the main tasks of building and maintaining infrastructure, ask for innovations that then are pushed to the projects. This usually happens in contests. An example is when the WVL department sets out an innovation contest or in the case of certain SBIR projects (Interviewee B, C, G, K, L, P, Q). Depending on the situation the innovation is in, the process it goes through is currently different.

6.1 General procedures

There are three procedures in place that will benefit all innovators, regardless of the situation (push, push-pull, pull).

First, there are procedures in place with regard to market uncertainty, that can be used by innovators in the earlier phases of innovation. For instance, RWS Expedition 2050 has created 4 scenarios of what the world, and specifically this industry could possibly look like in 2050. RWS has published the innovation agenda 2030 in which the ambitions and goals of RWS are published. The different focus point and transitions path teams have created roadmaps on how to achieve those ambitions. (Interviewee E)

These three types of documentation can be used at the front-end of innovation to make a preliminary assessment if potential innovations will fit in with these scenarios, ambitions, roadmaps, and thus needs of RWS, and therefore mitigate market uncertainty. The Innovation Agenda, Roadmaps, and Scenario Planning are systemic innovation policies in the category create space for actors' capability development. These are useful for solving actor's capability problems (Table 5).

Secondly, there are GPO Technical Experts. These are the experts that assess if innovations confirm with the list of accepted technologies and regulations, is authorized to develop criteria and a test plan, and to change the regulations and the lists of accepted technologies. This department aims to mitigate both final compliance and qualification method uncertainty. This procedure is a demand side innovation policy in the category of regulations.

These technical experts are experts in a specific field, like asphalt or concret, this procedure does not suffice when innovations are interdisciplinary or involve a digital component. For innovators it can be challenging to find the right experts. (Interviewee H, K, P)

Third, 2-phased contracts. This is a construct that is currently being developed. The aim of the developers is to mitigate market uncertainty in the final commercialization phase of innovation

(Interviewee E, S). Because two-phased contracts have not been fully implemented yet, it has been impossible to me to obtain more details about how it works, and how it tackles uncertainty.

6.2 Technology Push

In a technology push situation there are five procedures in place to mitigate uncertainty.

First, an innovator can contact the Innovation Loket (IL) for developing the business case. The IL will co-create the business plan, informing the innovator about who could be end-users, what procedures at RWS look like, and will connect the innovator to an intrapreneur that can take on the innovation from there (Rijkswaterstaat, z.d.-d). Figure 15 shows the work flow of the IL. The IL can, in this way, reduce technological uncertainty related to the use of the innovation, market uncertainty related to the customer needs and management uncertainty related to the business model. This procedure is part of the systemic policies in the category of interactions between system participants and the stimulation of the participation of actors.

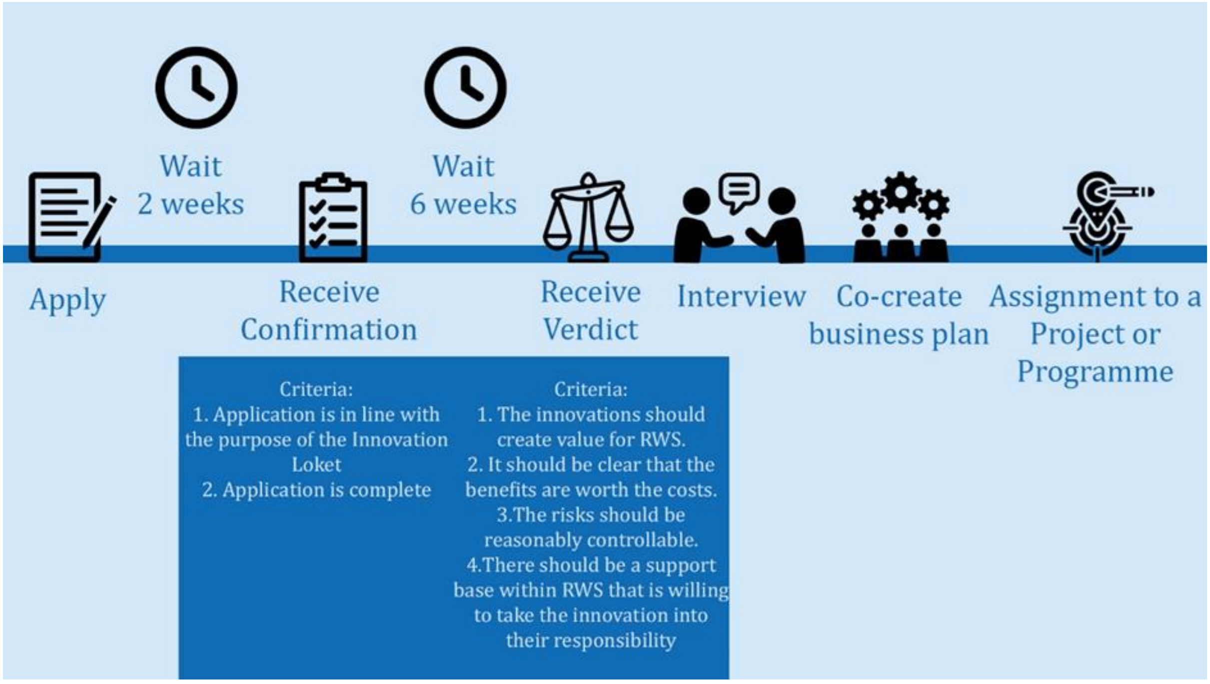

Figure 15: The Work Flow of the IL

Secondly, an innovator could collaborate with the CIP for fundamental research and lab testing conducted by research facilities. The CIP can support and finance research at research facilities to create opensource data that can then be used by innovators. For example, when the CIP is aware that multiple innovators are working on innovations that are in the same field and both them and RWS will benefit from the results (Interviewee E). This procedure mitigates technological uncertainty in the earlier phases of the process. Next to this possibility, there is also a department at RWS that is installed to foster the triple helix consisting of researchers, government and commercial parties. Together these two are part of the supply-side policy of facilitating and supporting public research.

Third, if the innovation involves Asphalt, the innovator can consult the Innovation Test Centre (ITC). The ITC will find the right GPO technical experts for their innovation and arrange a test location for the qualification tests (Interviewee A). With the experience gained over the years, the ITC has developed standard test road lengths as well as standard test periods for the different common test GPO technical experts need the results of for their judgement. These standards, however, are not communicated to innovators (Interviewee A). The ITC aims to mitigate qualification method regulatory uncertainty for asphalt related innovations. This procedure is part of the demand side innovation policy category; regulations.

Although the name would expect the ITC to test all sorts of innovations, in practice only asphalt and some related innovations are actually taken into consideration by the ITC. For other kinds of innovations, no similar procedures are in place (Interviewee E).

Fourth, is a new small-scale initiative, the Digicampus which only concerns digital innovations. The Digicampus is currently being installed and aims to work with three internal processes; Forum, Review Desk, and Landing. By which they will give a certain level of development support, assess the possibilities and help the innovation "land" in the organization (Interviewee M, N, O). The digicampus is a systemic policy focused on the actors and interactions.

Finally, there is GPO Innovation & Market (I&M) for innovators that can assign an individual to their innovation that could help. Employees within GPO I&M have a certain degree of freedom to do as they see fit (Interviewee I, F). There are for example, employees that focus on one innovation and aim to pull them through the maturation process, others do advocate for multiple innovation in a certain phase, for example. The freedom of choice complicates the uncertainty mitigation argument, in general the GPO I&M reduce user related technological uncertainty.

6.3 Market Pull

In a RWS pull situation there are two uncertainty mitigating procedures in place.

The project or department who initiated the pull is willing to function as a test and pilot location. One uncertainty present in a technology push situation that relates to technological, managerial, regulatory and time uncertainty is whether, where and when an innovator can test and pilot its innovation (Interviewee C, F, H, J, K, L, P, Q). In case of a market pull situation the puller functions as a test and first pilot location, eliminating uncertainty relating these aspects of the process. This procedure pertains to the demand side innovation policies of pilot and demonstration plants a public procurement for innovation.

Second, the innovation is partly navigated through the process towards maturity with a coordinated process by the body of RWS that initiated the pull. The innovator is supported in communicating with the end-users, finding the right GPO Expert for regulatory issues and financial support. This significantly reduces the development technological uncertainty, management uncertainty, and socio/political uncertainty.

6.4 Push-Pull

In a push-pull situation there are two procedures in place to reduce uncertainty. These procedures are systemic innovation policies.

First, the innovation is partly navigated through the process towards maturity with a coordinated process by the body of RWS that initiated the competition. The innovator is supported in finding end-users, the right GPO Expert for regulatory issues, financial support and, depending on the handler, test or pilot locations. This significantly mitigates the development technological uncertainty by providing a coordinated process and socio/political uncertainty by a certain level of stakeholder management.

Second, multiple innovations are pooled together and can learn from each other. This can mitigate technological uncertainty.

Interviewees show mixed feelings about these competitions. They value the coordination of the process, the ease of maturing the innovation in this way (Interviewee G, K, L). Nevertheless they are not always satisfied with the outcome. Innovators participate and spend heavily on maturing their innovation in the believe that RWS is interested in their innovation. This believe is fed by positive appraisals from employees and financial and practical support in maturing their innovation. At one point along the way to maturation, RWS declares one of the innovations in the competition the winner. However, in some cases winners struggle to find a pilot location. (Interviewee G, K, L)

6.5 Conclusion

This chapter answers SQ3: What procedures are in place at RWS to mitigate the in SQ1 defined uncertainties? The procedures can be categorized based on the situation in which they are implemented, which can be technology push, market pull, and push-pull. Table 8 presents the overview of the different procedures in place at RWS to mitigate uncertainties. Note that empty boxes in this table do not necessarily correspond to unsatisfied needs, or a field for improvement. It could, for example, be that these uncertainties are experienced, but not seen as problematic and therefor do not need procedures. Chapter 7 will follow with an analysis of industry's needs.

Tablel 8: Overview of the Procedures in Place at RWS to Mitigate Uncertainties.

Uncertainty:		General Procedures	Technology Push	Market Pull	Push-Pull
Technological Uncertainty				Pilot	Structured Process & Innovation Pools
	-Functioning		CIP		
	-Development				
	-Use		IL & GPO I&M		
Market Uncertainty				Pilot	
	-Customer Needs	Innovation Agenda, RWS Expedition 2050, Road-maps & 2-Phased Contracts	IL	Market Pull	Competition
	-Actions of Downstream Intermediaries	N.A.	N.A.	N.A.	N.A.
	-Actions of Competitors	N.A.	N.A.	N.A.	N.A.
	-Price Development of Substitutes	N.A.	N.A.	N.A.	N.A.
Management Uncertainty					
	-Exploration vs. Exploitation				
	-Metrics to Support Decision Making				
	-Business Model		IL		
Social/Political Uncertainty					
	-Conflicting Internal Interests				
	-Complicated Private/Public Relations				
Regulation					
	-Rule Content				
	-Final Compliance	GPO Technical Experts		Pilot	Structured Process
	-Qualification Method	GPO Technical Experts	ITC	Pilot	Structured Process
Time					
	-Time vs. Other Uncertainty				
	-Lead Times				

-Life Cycle				
-Timing				

7 The Needs of Innovators in the Industry

Innovators in the industry experience needs with regard to uncertainty mitigation that can be mitigated by RWS, in return for mitigating these uncertainties RWS will be able to obtain its goals by using the developed innovations. During the interviews innovators were directly asked what they need, latent needs were deducted from their stories, and RWS employees were asked what needs they observed. The needs are presented based on the uncertainty they are related to the most or are mostly associated with by interviewees. For example, pilots are under technological uncertainty even when pilots are helpful for more types of uncertainty. The list of needs constructed in this chapter will answer SQ4: To what extent do the procedures in place at RWS meet the uncertainty mitigation needs of innovating private organizations?

7.1 Technological Uncertainty

These uncertainties are related to the functioning, development, and use of the innovation. This uncertainty can be reduced by different supply-side policies such as facilitating universities and public research facilities in the earlier phases of development and by pilot and demonstration plants in the later phases.

At RWS there are teams working on these research capabilities on a broader scale, the CIP is in place to facilitate public research in innovation specific cases (Interviewee E & R), within RWS there is a dedicated department working on relationships with universities and research facilities.

The test and pilot facilities at RWS, however, bring additional uncertainties to the innovator. There is no process in place for selecting innovations nor pilot locations or their matching, and finding a pilot location often relies on the personal network of the innovator (Interviewees C, L, Q). Two different interviewees mentioned two different pilots regarding the same innovation without knowing about each other (Interviewee C & G). Both interviewees were happy with the results of the pilot in terms of electricity reduction of the innovation relative to the incumbent, but interviewee G immediately noted that factors as the production and recyclability of the product were not included in the final evaluation. Interviewee B mentioned that the criteria of the pilots he was involved in were completely determined by the company without RWS involvement.

Another problem is that pilot goals and success criteria are not clearly set before the pilot (Interview C, G, I K, L, participant observation 2, 3, 4)). This causes incomplete pilots and repiloting. At the ITC they only test for construction characteristics (Interviewee A) and innovators have experienced needing to do a second pilot as different stakeholders demanded new ones because their criteria had not been taken into account (Interviewee K). In participant observation 4 one participant noted that they keep piloting, but never mature into regular practice.

Regarding technological uncertainty, **N1: innovators need a structured approach towards testing and piloting.** This need is twofold, first, a structured approach retrieving all the criteria from all the relevant stakeholders before the start of the pilot and strict agreement on when a pilot is a success or not. Second, a structured approach towards matching innovations to possible pilot locations.

7.2 Market Uncertainty

Market uncertainty is, within this study, mostly related to customer needs. Customers in the infrastructure industry are RWS, provinces, municipalities and Schiphol, of which RWS is responsible for an important share of the demand. The general higher level of the demand from RWS can be derived from climate agreements, the “bestuursakkoord”, and if the innovators is familiar with them, the RWS2050 scenarios, the Innovation Agenda, and the Roadmaps. These documents, however, only give a generalized idea of the direction of the needs and are just put online on different URL's. **N2: Innovators need RWS to articulate their needs (Interviewee H, J, K, P, Q).**

The more specific needs come from the end-users and other stakeholders. Being market oriented is crucial for the innovator to develop a successful innovation (Dougherty, 1990; Jaworski & Kohli, 1993; Leonard-Barton, 1998; Narver & Slater, 1990; Slater & Narver, 1994). Leonard-Barton (1998) Claims that during innovation there is no information more important that the information flowing in from the market as it shapes the sciences into usable products and services. Deriving latent needs as well as generative learning are important aspects of innovation (Slater & Narver, 1998). Customer observations in real-life settings and continuous experimentation (linking back to the need for pilots) are an important part of a this pro-active market orientation (Slater & Narver, 1998). In the earlier phases of an innovation, reoccurring contact with these stakeholders is crucial for developing an useful and valuable innovation (Cooper et al., 2002a). **N3: Innovators indicate that they need more direct contact and interactions with stakeholders in order to reduce market uncertainty (Interviewee H, J, K, P).**

Another important source of uncertainty in the area of customer needs is organizational dissonance. As goals and ambitions are not aligned throughout RWS, needs expressed by one part of the organization can be unrecognized by other parts (Interview E, G, K, L, P, Q)). RWS sets out idea contests, SBIRs or other challenges in the market regularly. Participants of these programs indicate that their innovation is left unused after participation or even winning as the programs were not set out for real-life organizational needs and were conducted without the involvement of the right stakeholders (Interviewee G, K, L, P, Q). **N4: Innovators need organizational alignment, they need RWS to internally agree on what the needs are.**

Below a citation of Interviewee K is presented, he sets out the situation related to need 5. It also illustrates the earlier evaluation of the push-pull situation. Innovators are motivated to develop innovation by verbal appreciation, small-scale financial compensations and the availability of other resources, after which RWS adjusts its requirements, or perhaps no pilot locations are available, or the developed innovation might not be procured. The innovators are let to projects to meet societal goals, but they feel abandoned when they try to innovate to meet those goals (Interviewee H, J, K, L, P, Q).

"*And that setup [SBIR], that setup is very cool. I agree with that for the most part, just not quite. You challenge a market, you set a reward for it. [..] But if you then look, the hours that are in it, you cannot cover them with that reward. [..] Only, the difficult thing in that is… Yes, there is no horizon, there is no horizon. [..] what is actually missing is that last candy in which they say 'you know, if you have gone through that entire SBIR trajectory, well then we also make four locations available where you can build the bridge*." -Interviewee K

Procurement departments, and project managers have evaluation criteria such as time, scope and budget, where departments working on innovations are considered with the focus points set by the board with regard to for example, digitalization and sustainability. Public Procurement for Innovation can set out tenders in a way that they fit the set goals and focus points.

As interviewee K sets out, the concerns and needs of innovators regards an horizon, they need to know that when they develop something solving customer needs, that they will actually be purchased. **N5: Innovators are in need of Public Procurement for Innovation (PPI).**

7.3 Management Uncertainty

A constant challenge for all innovators is with being ambidextrous, exploit what they are already good at while exploring what they can do in the future (Andriopoulos & Lewis, 2009; Birkinshaw & Gibson, z.d.; Lavie et al., 2010). The core task of RWS is to build and maintain the infrastructure in the Netherlands, this is done in a highly standardized way with a focus on time and budget and a strict management top-down hierarchy (Interviewee C, E, F, M, N, O, Participant observation 1, 2, 3, 4).

On the other hand, innovation efforts are bottom-up and scattered throughout the organization. Initiatives, such as presented to the Innovation Loket, to support innovators sprout from all different departments and there is no central coordination (Interviewee A, B, C, D, E, G, I, K, L, M, N, O, P). Specific needs are set out in the market by users or departments that then struggle to get higher managerial approvement and financing for the designed solutions (Participant observation 2, 3, 4). Especially if an innovation involves multiple departments, intrapreneurs at RWS who want the innovation implemented struggle to find someone authorized to make decisions as it is neither one of their departments (Interviewee C, R, participant observation 3, 4).

Uncertainty arises from not knowing where in the top-down organization, the innovators and intrapreneurs should introduce their bottom-up initiatives in order to have decisions made and financing become available. Choosing the wrong top-down stream can result in a death-end for the innovation (Participant observation 4).

There is a need for innovators, intrapreneurs and ambassadors to know where to go, who makes decisions and where to get financing. **N6: Innovation needs to be assigned a place within the organization RWS.**

As the different initiatives, intrapreneurs, and innovation needs are fragmented over the different departments top-down hierarchies, innovations reach dead-ends when they are ready to mature into a next phase. “My work here is done” is the philosophy of the Innovation Loket, or the Pilot Location, as soon as they have finished their job, there is no hand over from phase to phase, nor anyone with the responsibility to mentor the innovation into the next phase or to the next department (Interviewee A, B, C, E, F, G, I). Currently individual ambassadors take on this role from their intrinsic motivation and believe in the value of the innovation, these ambassadors can be from all different kinds of fields and departments and have no innovation management knowledge nor experience (Interviewee C, F, I). Finding such an ambassador depends on the network of the innovator and often takes a lot of time, it is a highly uncertain process.

For example, in the case of “Verjongingscreme”, an innovation to extend the life time of asphalt. The first time RWS got involved with, and invested in that idea, was approximately between 2008 and 2010, the employee who now functions as the ambassador of this innovation started working on this innovation by 2020, while he was first contacted about the innovation in 2014. All this time the innovation is not mature yet. (Interviewee I)

N7: There is a need for a coordinated process with N8: someone in charge from ideation till implementation, both in order to prevent innovations unintentionally getting stuck in the funnel towards maturity. Best-practice research shows that those that successfully innovate have an idea-to-launch system (Cooper et al., 2002a, 2002b).

This need for knowing who has authority and who is responsible, is aligned with needing to know how, when and who makes decisions on whether or not to move an innovation into the next phase. **N9: There is a need for knowing who makes the decisions.** After each phase there should be a decision, an evaluation, a gate. Does the innovator want to move the innovation to the next phase and does RWS? Gates without teeth or with hollow decisions without financial support are common mistakes in innovation processes (Cooper, 2008). **N10: There is a need for consequences of decisions,** when innovations get killed, there should be no further efforts and when innovations are a "go" they should be assigned more resources.

Currently, innovators are in the dark about why their innovation is supported or rejected (Interviewee H, J, K, L, P, Q). An analysis of the interviews with RWS employees shows that innovators are not aware of the metrics which support innovation related decision making, guts and personal interests of those involved are of great influence for the chances an innovation is given (Interviewee A, C, F, I, Participant observation 2, 3, 4). Internally, the network of those involved is an important indicator for the ability to receive financing and support (Participant observation 2, 3, 4).

N11: Innovators need structured and transparent decision making.

An important part of innovation is that it has to be implemented in practice. The end-user has to adopt the innovation into their processes and routines. It is important to be aware of the concept of a "stony buyer", one who would benefit from the innovation but needs convincing to use it (Gourville, 2006). The willingness to adopt innovations is affected by amongst other things; (1) the endowment effect, that represents people valuing what they have more than what they might gain, and (2) the nine time effect, people overweight the incumbents benefits 3 times and the innovators overweigh their innovation by 3 times (Gourville, 2006). Currently, at RWS actions to pursue "stony buyers" are limited to showing them the benefits (Interviewee B, F, I, M, N, O). People and work processes have to change in order to become more effective, efficient, or sustainable, for example.

Change is a complicated concept that can have a big impact. In order to make sure that change is effective, it needs to be managed. **N12: There is a need for professional change management that can mitigate uncertainty pertaining to the effects of "stony buyers".**

7.4 Socio/Political Uncertainty

The first uncertainty that falls in this category is the uncertainty related to diverse interests, diverse interests between the innovator and RWS and between different RWS departments. These uncertainties are interrelated to market uncertainty and management uncertainty, respectively. The most relevant diverse interests between RWS and innovators is the type of win they aim to get from it. Innovators need to make a profit where RWS needs to obtain social value. The different views and interests of RWS employees and innovators makes it hard to predict each other's actions (Hall & Martin, 2005).

Internal conflicting interests are problematic for innovators in the sense that innovators deal with innovation departments with, for example, sustainability goals until they are matured and ready to be procured. Then the procurers only have scope, time, and money goals (Interviewee E, G, K, I, P, Participant Observation 2, 3, 4). Currently, when an innovator needs any kind of support from RWS the innovator contacts personal contacts within RWS to find one willing to support. In one example an innovator called asset managers from different regions in a geographic order, innovators do this when they know from previous experiences that this is fruitful to just keep asking at different entities until one sees value in the innovation (Focus Group). It is however highly uncertain which entities do or do not see value in the innovation. After that one form of support both the innovator and the relevant RWS employees wonder why the innovation does not mature any further (Interviewee G).. **N13: Innovators need a central point of contact.**

Even when decision makers are informed well and use decision guidelines, decisions will always be influenced by internal politics and value judgements (Hanft & Korper, 1981; York & Venkataraman,

2010) **N14: Innovators are in need of adequate stakeholder management. (This is related to N3: Innovators indicate that they need more direct contact and interactions with stakeholders in order to reduce market uncertainty.)**

Another source of uncertainty in this category is related to the relationship between RWS and the innovators. There is the need for RWS "to get out of their ivory tower" (Interviewee K). **N15: There is the need for regular bilateral contact (Interviewee H, J, K, P, Q).**

7.5 Regulatory Uncertainty

Within the category of regulatory uncertainty, the most prevailing uncertainty arises from the qualification method. RWS has procedures in place in which technical experts set out criteria and when those are met, the innovation will be added to the list of accepted technologies (Interviewee A, F, G). The problem, however, is concerning the process of finding the right experts that have this authority for the specific innovation, innovators struggle with getting in to contact with experts in general (Interviewee H, J, K, P). Innovators struggle when their innovation is multidisciplinary and not just a new type of concrete or asphalt, which experts has to consulted then (Interviewee P). In case the innovation contains a digital component the situation is utmost unclear (Interviewee H, J), some of the interviewees were unable to tell me where to go to admit new technologies (Interviewee M, N, O).

N16: Innovators are in need of clear and up-to-date qualification methods.

Final compliance uncertainty is present in the way that it is sometimes unclear to RWS employees whether they are legally allowed do perform certain actions, or not (Interviewee B, E, F, K, P, Q). The employees make an impression of being afraid to accidently give state aid, break international trade laws, or unlevel the playing field (Interviewee B, E, K, P, Q). The interviewed RWS employees also did not agree on what is and what is not allowed (Interviewee B, F).

N17: There is a need for those working on innovations within RWS to know the regulations and how to comply with them.

7.6 Time Uncertainty

Related to the concept of time, uncertainty regarding the time from idea to launch is of importance. Innovators prefer that as fast as possible (Interviewee K, P, Q). Previously discussed uncertainties might extend the process.

The other construct is timing. Timing plays an important role in finding test and pilot locations. First, an innovator is depended on its personal network to find an RWS employee to incorporate the pilot (in a technology push situation) in its project and then this project has to be in a phase in which it is still possible to do so. Conversely, in a market pull situation, the innovators have to propose an innovation before the project moves on without it. The timing of when contests are out and for what characterizes the difference between a push and a push-pull situation.

Timing uncertainty is highly interrelated to the other uncertainties. **N18: innovators need the other uncertainties mitigated in order to mitigate uncertainty related to time.**

7.7 Conclusion

In this chapter 18 needs have been identified. These needs are summarized in table 9. Attending to these needs will mitigate the uncertainties that innovators experience. By attending to these needs RWS ensures that the right innovations become available to contribute to their goals. The needs articulated in this chapter will be used as design criteria for the solution. The solution, an answer to these needs, will be designed in the following chapter, chapter 8.

Tabel 9: The needs Innovators Experience Regarding Uncertainties. Based on interviews and participant observations.

Uncertainty:	Needs:
Technological Uncertainty	N1: Innovators need a structured approach towards testing and piloting.
Market Uncertainty	N2: Innovators need RWS to articulate their needs. N3: Innovators indicate that they need more direct contact and interactions with stakeholders in order to reduce market uncertainty. N4: Innovators need organizational alignment, they need RWS to internally agree on what the needs are. N5: Innovators are in need of Public Procurement for Innovation (PPI).
Management Uncertainty	N6: Innovation needs to be assigned a place within the organization RWS. N7: There is a need for a coordinated process with N8: someone in charge from ideation till implementation. N12: There is a need for professional change management that can mitigate uncertainty pertaining to the effects of "stony buyers". N9: There is a need for knowing who makes the decisions. N10: There is a need for consequences of decisions. N11: Innovators need structured and transparent decision making.
Social/Political Uncertainty	N13: Innovators need a central point of contact. N14: Innovators are in need of adequate stakeholder management. N15: There is the need for regular bilateral contact.
Regulation	N17: There is a need for those working on innovations within RWS to know the regulations and how to comply with them. N16: Innovators are in need of clear and up-to-date qualification methods.
Time	N18: innovators need the other uncertainties mitigated in order to mitigate uncertainty related to time.

8 Solution Design

There are 6 main categories of uncertainty that are inherent to innovation and that could obstruct innovations from maturing. Mitigating these uncertainties should ensure that the desired innovations become available to RWS. This chapter will answer SQ5: How can RWS improve the mitigation of uncertainties in the commercialization of innovations in the infrastructure industry?

From the analysis of the interviewee data and participant observations, I have observed that there are several uncertainties that affect innovations and that there are several procedures in place at RWS to mitigate them (Table 8). Interviewees have suggested that there are 18 needs which need to be covered to cope with the experienced uncertainties (Table 9). The common denominator of these needs is the need for a more structured approach towards innovation.

During this study the problem at hand turned out to be highly complex. As described in chapter 1, innovation at RWS involves multiple departments that all need to put efforts towards the solution. Analyzing the problem from an uncertainty management perspective narrowed the problem but resulted in 6 uncertainty categories and 18 uncertainty related needs. There is no possible single solution that could attain these needs. It is therefore that a battery of solutions is proposed. The different solutions together can attend the 18 needs. The solutions involve implementing different types of innovation policy as well as structuring the different innovation efforts in general. A final component of the solution mix is implementing set review moments before certain resources are dedicated to an innovation.

The designing of the recommendations was inspired by multiple factors in both the study itself as well as in the university education that was in prior to this thesis. First, during the interviews innovators not only expressed their needs, they also gave examples on how private customers or other governments conduct their practices, as well as their own ideas of what RWS can do. Second, the structure of the process is built on a synthesis of the knowledge from the different courses of the (managing innovation processes track of the) innovation management master. Third, the types of innovation policy that are advised directly follow from the in chapter 5 defined possibilities for the in chapter 7 defined needs.

Next, I propose 7 solution parts to provide an answer to the 18 needs, based on existing literature. Table 10 contains a summary of the needs and how the proposed measures may help cover those needs. Before designing an innovation process for RWS that fits the needs of the innovators, it is important to understand the innovation process that innovators implement. The innovation process of the innovator can then be used to structure the different solution for RWS based on the chronological order that the innovator needs them in.

Table 10: The 18 Identified Needs and the Type of Solution Proposed for it.

Need	Solution
N1: innovators need a structured approach towards testing and piloting.	PDPs
N2: Innovators need RWS to articulate their needs.	Innovation intermediary
N3: Innovators indicate that they need more direct contact and interactions with stakeholders in order to reduce market uncertainty.	Innovation intermediary

N4: Innovators need organizational alignment, they need RWS to internally agree on what the needs are.	Idea-to-Launch System (Management)
N5: Innovators are in need of Public Procurement for Innovation (PPI).	PPI
N6: Innovation needs to be assigned a place within the organization RWS.	Idea-to-Launch System (Management)
N7: There is a need for a coordinated process.	Idea-to-Launch System
N8: someone in charge from ideation till implementation.	Innovation intermediary
N9: There is a need for knowing who makes the decisions.	Review Committee
N10: There is a need for consequences of decisions.	Review Committee
N11: Innovators need structured and transparent decision making.	Review Committee
N12: There is a need for professional change management that can mitigate uncertainty pertaining to the effects of "stony buyers".	Change Management
N13: Uncertainty with regards to diverse interests stresses the need a central point of contact for innovators.	Innovation intermediary
N14: Innovators are in need of adequate stakeholder management.	Stakeholder Management
N15: There is the need for regular bilateral contact.	Innovation intermediary
N16: Innovators are in need of clear and up-to-date qualification methods.	Qualification Methods
N17: There is a need for those working on innovations within RWS to know the regulations and how to comply with them.	Idea-to-Launch System (Management)
N18: innovators need the other uncertainties mitigated in order to mitigate uncertainty related to time.	Idea-to-Launch System

8.1 Idea to Launch System

In order for RWS to create a structured innovation process it should be the first step to know what the process of the innovators looks like. A generalized process can be constructed that serves as the base for the process at RWS. Companies that successfully innovate often rely on a structured idea to launch process, such as the stage-gate process (Cooper et al., 2002a; Cooper & Kleinschmidt, 2001). Innovators from the industry implement idea to launch processes that are all in line with the stage-gate model (Interviewee H, J, K, P, G).

The main concept of stage-gate is that the idea to launch process is built with stages, in which different departments simultaneously work on the innovation, and gates, in which a review committee determines whether the innovation moves to the next phase or not and assigns resources in case of a go decision.

All innovations begin with an idea in the ideation stage, after which the initial screening takes place. Criteria in this stage concern feasibility, strategic alignment and degree of advantage. When these criteria lead to a go decision, the preliminary investigation starts in which a preliminary market and technical assessment are made. In the second screening, the same criteria as in the initial screening are common, although more concrete descriptions are needed. Stage 2, building the business case, comprises of a customer needs study, concept testing, feasibility analysis, manufacturing appraisal, legal assessment, and a detailed financial analysis. In screening 3 the resources to start developing are assigned and therefore there are strict criteria here, the product definition is signed off. In stage 3 all the technical work is done, including all the lab testing, while the steps of stage 2 are iterated. It is also in stage 3 that regulatory issues are resolved. In screening 4 it is assessed if there is developed what was intended to develop and all other criteria from before are reassessed. Stage 4 is about testing and validating the innovation. It is tested if the innovation works as intended in the actual use conditions, how the users receive the innovation, and if the production process is optimal. A final financial analysis is made in order to make the final launch decision. In screening 5 the decision is made to launch the innovation. Stage 5 is the launch of the innovation, after which a post-implementation review will take place. Figure 16 shows the stage-gate based idea to launch process of the innovators in the industry (Cooper & Kleinschmidt, 2001). This process can now be used to determine the chronological structure of the different solutions proposed here for RWS.

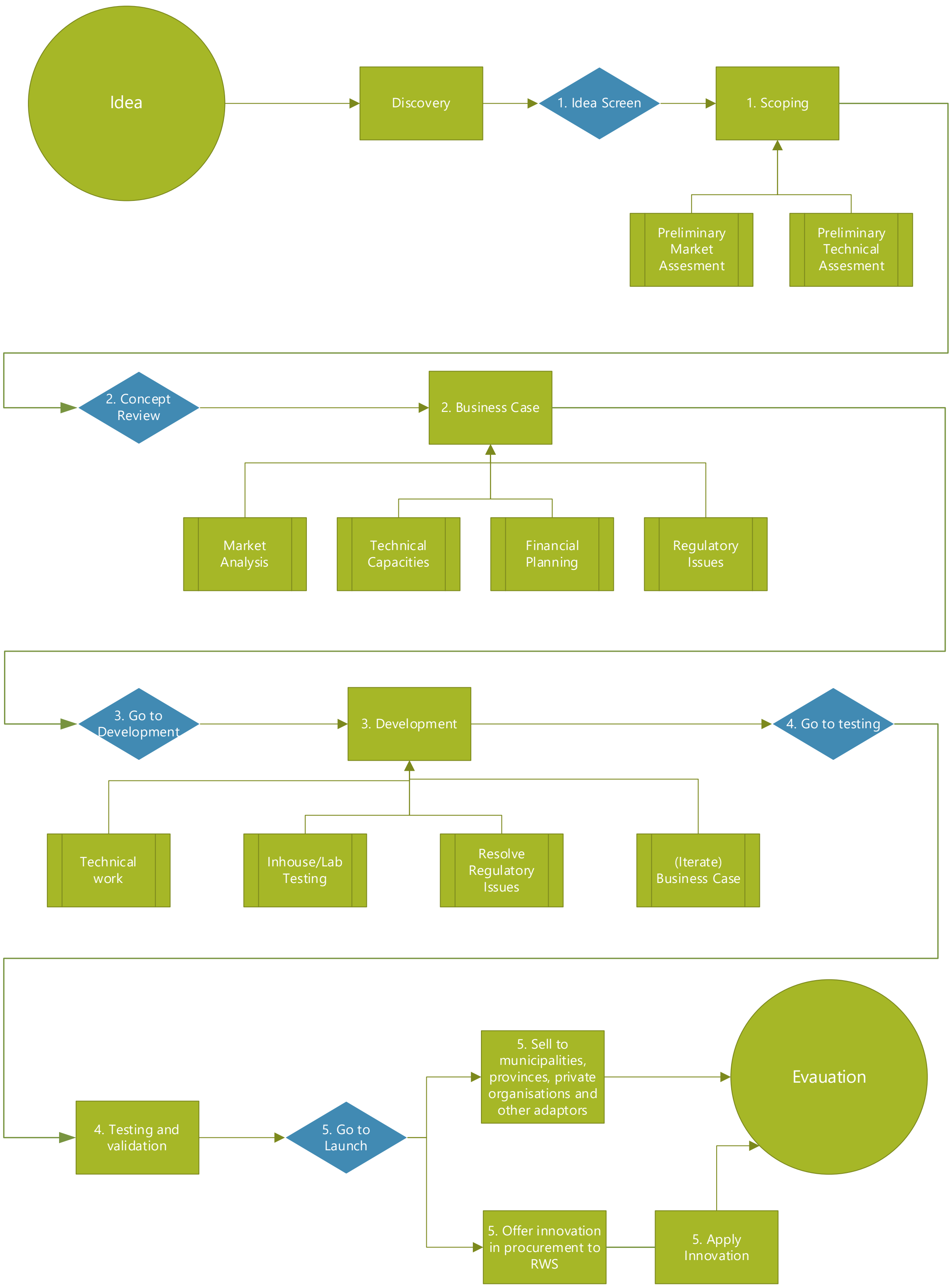

Figure 16: The Generalized Idea-to-Launch Process of Innovators (Based on Stage-Gate by (Cooper & Kleinschmidt, 2001))

RWS is in need of an idea to launch system that focuses on uncertainty reduction in maturing innovations. Above, in figure 16, a generalized representation of the innovation process of innovators in the industry is presented. This knowledge of the process of the innovators can now be used to structure an idea to launch process for RWS that satisfies all the in chapter 7 defined needs. The newly designed idea to launch system should hinge on the innovator's innovation process so that the optimal outcome can be generated from both parties' efforts.

This idea to launch system of RWS should consists of steps in which RWS takes uncertainty mitigating actions and steps in which RWS critically evaluates the innovation every time before new resources are going to be invested. In this chapter a detailed description of these steps of uncertainty mitigating actions is provided, as well as a detailed description of how the critical evaluations should take place.

Figure 17 shows the designed idea to launch system for RWS. The basic structure is provided by the idea to launch process of the innovator. The different solutions to the different needs are presented in relation to the innovator's process. A blue diamond represents a review moment and an orange square represents an uncertainty mitigation action by an RWS department. The blue lines represent resource commitment, orange lines are action handovers or information flows. Possible iterations of actions or definitely stopping an innovation after a negative review are not drawn, but are possible. Next to the proposed solutions, procedures that are already in place at RWS should be integrated into this idea-to-launch system. For the sake of the readability of figure 17 only the newly designed solution is presented. Each of the proposed solutions visualized in figure 17 will be elaborated in the following subsections.

Note: This drawing and explanation are linear, the factual process will not be.

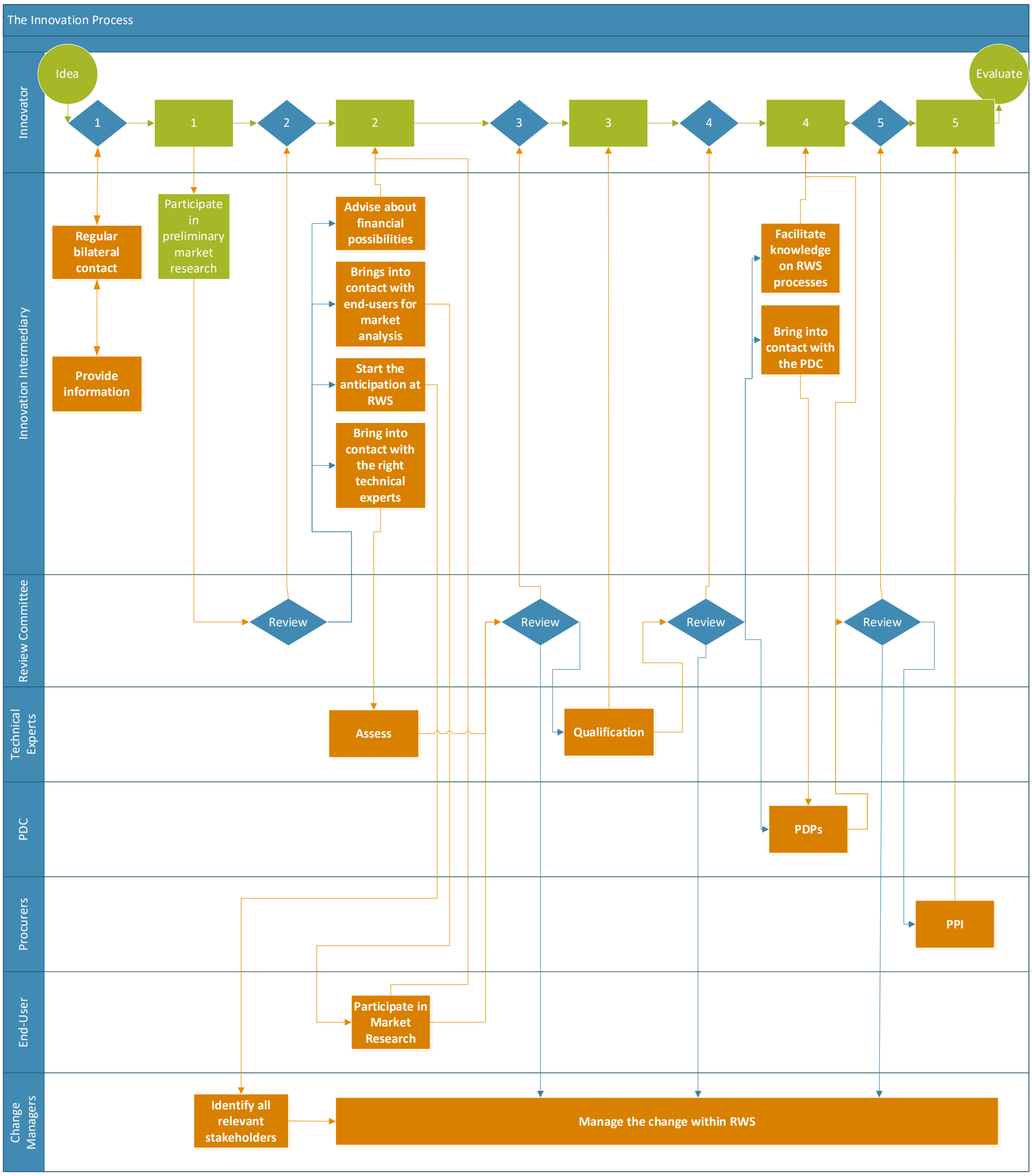

Figure 17: The Idea to Launch System of RWS

The following subsections will each introduce one part of the solution mix. It is important to note that all solutions together form the optimal solution. Together, these parts will form one integrated process that mitigates uncertainties and matures innovations. With implementing these solutions RWS will be reaping benefits in the form of innovations in the market that will contribute to the set goals. This total system will mitigate the different uncertainties and therefore mitigate the time related uncertainties (N18).

8.1.1 Management

In this chapter an idea to launch system will be introduced and all relevant actors and actions are explained. This system provides a level of structure that is needed to prevent innovations to be unintentionally blocked along the maturation process. One important aspect of this system is to assure that all actors are coordinated and aligned (N4) and that innovation is assigned a place withing the organization (N6). A final aspect is that now it is clear who is concerned with innovation and who is not, management can assure that those who are, are familiar with all the possibilities and regulations (N17).

The recommendation is to have one innovation coordinator in charge of all of the innovation efforts. With a small support staff of innovation managers in charge of streamlining these recommendations for the idea to launch process, ensuring all relevant and available knowledge is incorporated and doing support activities. The innovation coordinator will be the coordinator of the elaborated teams, the innovation coordinator is also the chairman of all the review committees that evaluate the innovations. It would be best to have this innovation coordinator report to the HID of WVL (Interviewee R, T).

8.2 Innovation Intermediaries

The first four needs that are attended to are: articulated needs (N2), someone in charge from ideation till implementation (N8) , a central point of contact for innovators (N13), and regular bilateral contact (N15). These needs can be categorized as resulting from problems in the interaction between the participants of an innovation system (Wieczorek & Hekkert, 2012). When problems arise that relate to the interactions amongst innovation system's participants, Wieczorek & Hekkert (2012) advise to implement public policies that stimulate the occurrence of interactions and that prevent too strong and too weak ties between the actors (Table 5). Examples of such policies are collaboration schemes, constructive technology assessments, and debates, as well as the later elaborated PPI (Table 4). The current set up in which RWS sets out challenges and appoints a winner is also an important example in this category.

The solution to these needs in the relational part of the innovation system are innovation intermediaries. These intermediaries facilitate the process of interacting in exchange relationships (Todeva, 2013). One important aspect of that is facilitating a steady stream of two-way communication (N15: regular bilateral contact). Todeva (2013) describes multiple forms, types and contexts of these intermediaries, of which the following tasks should be implemented by the intermediaries at RWS.

First, intermediaries should assist in finding the needed resources that RWS has to offer and enabling to use them (Todeva, 2013). The intermediary advises about financial solutions, provide information about the different processes and possibilities, and arranges assessments from the later introduced review committees that have the ability to assign the resources. (N8: someone in charge from ideation till implementation & N13: a central point of contact for innovators)

Secondly, the role of an intermediary can be in the form of supplier relationships between RWS and their innovation suppliers (Todeva, 2013). In the RWS context the intermediaries take on the responsibility to build good innovation supplier relationships in the form of keeping the supplier up to date about the needs RWS experiences and giving feedback on the usability of ideas that the innovators come up with. (N2: Innovators need RWS to articulate their needs)

As defined in chapter 7, being market oriented is crucial for the innovator to develop a successful innovation (Dougherty, 1990; Jaworski & Kohli, 1993; Leonard-Barton, 1998; Narver & Slater, 1990; Slater & Narver, 1994). Leonard-Barton (1998) Claims that during innovation there is no information more important that the information flowing in from the market as it shapes the sciences into usable products and services. Deriving latent needs as well as generative learning are important aspects of innovation (Slater & Narver, 1998). Customer observations in real-life settings and continuous experimentation are an important part of a this pro-active market orientation (Slater & Narver, 1998). In the earlier phases of an innovation, reoccurring contact with these stakeholders is crucial for developing an useful and valuable innovation (Cooper et al., 2002a). The innovation intermediary at RWS should also always be the starting point for innovators that are being market oriented. This means that the innovation intermediary provides the innovator with information about the explicit needs and goals of RWS, participates in preliminary market research, and brings the innovator into contact with the relevant RWS stakeholders for market research.

A summary of the responsibilities of the innovation intermediary:

- Provides all the needed information about explicit needs and goals of RWS (Discovery).
- Participates in the preliminary market assessment (Scoping).
- Brings the innovator into contact with the end-user for the market analysis (Business case).
- Supports with information about the different possibilities in the financial planning (Business case).
- Brings the innovator into contact with the right technical experts in order to assess potential regulatory issues (Business case) and create criteria and a test plan and location (Development).
- Facilitates all the knowledge about RWS processes needed for the technical work (Development).
- Starts the anticipation process at RWS, making sure that employees are ready for what is to come (Development).
- Bring the innovator into contact with the Pilot and Demonstration Team (Testing & Validation).
- Makes sure that RWS relevant employees are familiar with the innovation (Launch).

8.3 Review Committee

When a central point of contact from ideation to launch is installed that has clear communications with the innovator, the next step is to assure this entities authority. There is a need for knowing who makes decisions (N9), for decisions with consequences (N10), and for transparency towards innovators on how decisions are made (N11). Where corporate innovators implement an iterative system of work and evaluation blocks, RWS can implement decision moments that are based on this same philosophy.

At these set moments in the development of the innovation the innovation intermediary brings the innovation in front of the review committee (Cooper, 2008; Cooper et al., 2002a; Cooper & Kleinschmidt, 2001) at which the innovation is designated a go or kill destiny. The committee should consist of senior management, those who own the recourses needed, team members from the relevant goal teams, technical experts, purchasing, and project managers. Depending on the innovation the innovation intermediary can add certain experts to the team for a specific innovation and in the earlier gates. First, the review committee assesses the innovation using “must meet” criteria that need to be present and “should meet” criteria on which the committee assigns a grade ranging 0-10. It is important that these criteria are discriminating, realistic, and operational. The criteria are based on an absolute set of standards, such as strategic alliance. Secondly, the review committee assesses the innovation from a portfolio perspective. This part of the meeting is about the available resources and if similar projects might already be in the funnel, these concern relative standards. The earlier assigned grades can be useful in this phase as well as the roadmaps that have been made by RWS. If decision is to proceed with an innovation, this meeting is also used to agree on the criteria that are going to be used in the next review session and which recourses will be available in the next stage. It is of great importance that the results of these meetings are shared with the innovators.

8.4 Stakeholder Management

For innovators there is a need for direct contact with stakeholders (N3) and adequate stakeholder management (N14). In order to be successful it is crucial to be concerned with the different stakeholders from the beginning (Pacagnella Júnior et al., 2015) and that managers make the relevant stakeholders aware of the benefits of the innovation (Olander & Landin, 2008). All kinds of different models for stakeholder management have been developed such as the ten-step stakeholder management model (Colle,2005), business support optimization (Green & Jack, 2004), or on overcoming stakeholder conflicts (Boerner & Jobst, 2011). In order to engage stakeholders, firms should have operational capabilities, engagement management capabilities, the capability to make use of contrasting views to reframe problems and values and the innovator should be able to learn from the cooperation, so that innovators can take advantage of the conflicting interest (Watson et al., 2018).

In their systemic literature review Pedrini & Ferri (2018) find three phases of stakeholder management strategy development, strategy execution, and performance measurement that innovators can structure their stakeholder management with.

The innovation intermediary is responsible for bringing the innovator into contact with the end user early on, but end-users are only one of the categories of stakeholders involved in innovations. Recourse owners are another important stakeholder that direct contact is needed with in order to secure the needed resources. The innovation intermediary constructs the review committee the innovation is evaluated by, in which also the relevant resource owners take place. It is therefore that the innovation intermediary also is the intermediary between the innovator and this stakeholder category. It can, however not be the tasks of the innovation intermediary to manage the different stakeholders as he/she is the impartial intermediary that has a pure coordinating support role.

A first big step in stakeholder management is identifying the *relevant* internal and external stakeholders, this is that innovators are not able to do their selves because of a lack of knowledge about RWS. The topic of change management that will follow below will elaborate on how to manage the change that internal stakeholders will experience. Stakeholder and change management can be practiced by one dedicated team, which will be concerned with identifying the relevant stakeholders and managing the internal change.

8.4.1 Change Management

An important part of innovation is that it has to be implemented in practice. “Stony buyers” at RWS are problematic for the maturity of innovations (Interviewee A, C, E, G, I, M, N, O, Participant observation 2, 3,4). Innovators are in need of change management (N12).

Resistance can be minimized by making behaviorally compatible innovations (linking back to the need for market orientation) or by finding believers (Gourville, 2006). RWS should install a team of change managers that can be brought in to ensure that RWS as organization is ready for the changes that come with the innovations. Through history multiple models and philosophies have been developed (Examples are: Bullock & Batten, 1985; Kotter, 1996; Lewin, 1951) that could be of positive influence on the implementation of innovation within RWS.

8.5 Qualification Method

Innovators are in need of clear and up-to-date qualification methods (N16). RWS has a system in place with technical experts that can determine test criteria and have the authority to change regulations and add innovations to the list of accepted technologies. There are however, no experts for digital areas, nor experts for interdisciplinary innovations (Interviewee M, N, O, P). For innovators it is hard to find the right experts to match their innovation (Interviewee H, J, K, P).

First, it is crucial that an overview is created with who are technical expert with authority on what topics. Second, the list should be constantly assessed by the innovation intermediaries, who know what is going on in the market, who then determine in what fields experts are needed. The right experts should be found to match with these needs from the innovation intermediaries.

The innovation intermediary is the intermediary who makes sure that the innovator is in contact with the right experts and that the right experts are on the review committee. Introducing regular bilateral contact between innovators and the experts assures that the right qualification processes can be in place and regulations can be fitted proactively. The experts should together set up an information flow towards the innovators on the possibilities for qualification so that they can be prepared and detect possible problems early on. (Bonnin Roca & O'Sullivan, 2020; Link & Metcalfe, 2008; McCray et al., 2010; Petersen & Bloemen, 2015)

Big steps can be made in the field of modelling and simulating. Currently, these options are only used occasionally (Interviewee A, G), while they can ease the qualification process (Bonnin Roca & O'Sullivan, 2020). When those options are not feasible, a physical PDP is important for the qualification.

8.6 Pilots and Demonstration Plants

Pilot and Demonstration Plants (PDP) are essential for reducing uncertainty and maturing innovations (Hellsmark et al., 2016), innovators in the industry are in need of a structured approach towards piloting innovations (N1). Omitting to install support programs for different types of pilots in the different phases of the innovations maturity will result in innovations not making it to maturity and being unintentionally stopped along the maturation process (Hendry et al., 2010).

In order for RWS to start piloting in a more effective and efficient manner it is recommended to assign the responsibility for PDPs to a designated team withing the organization. These tasks should ideally correspond to ITC, under the current organizational structure. ITC would be in charge of all the testing, demonstrating, piloting, and similar activities. One place to go to for everything related to this, also in favor of the need for a more understandable, structured process and the need for innovation related aspects to be assigned a clear place within the organization. This team is in direct contact with the one in charge of the innovation from idea to launch and all relevant stake holders. Important is the contact with the technical experts that are in the authority to solve regulatory issues, PDPs are an important part of the qualification method.

First, the mission of this team is to implement the following definition of PDP: "A demonstration project [PDP] is defined as a finite initiative to test a technology according to the project objectives."(Karlström & Sandén, 2004). In this definition two important factors are noted. First, a demonstration project is finite, relevant stakeholder agree on the duration of the project beforehand. Second, the technology is tested according to the predetermined project objectives that have been constructed with the relevant stakeholders. Assuring these two important factors in PDPs at RWS will already substantially mitigate the currently experienced uncertainty.

Second, the challenge is to set goals, resolve goal conflicts and stimulate a mix of actors in the PDP network (Hellsmark et al., 2016). The team works to align the goals and visions of the different PDP participants before the start of the projects as there is a great risks of conflict of interest possible.

Third, the team assesses the PDPs before and after their involvement in order to stay aligned with their purpose. Criteria that can be used for assessing the PDP ex-ante:

- Will we learn things that can be used in the development?
- Can this project help open up the market by creating awareness and identifying barriers?
- Will this PDP help form a network of actors that can influence the development and political process?
- Economic and technical feasibility
- Competence of the project team
- The size of the project must match the set objectives
- Timing, do not test what has been proven already, nor what is not yet ready to be proven

Criteria for assessing the PDP ex-post can be divided in direct project results and indirect process results. In earlier maturation phases generating new knowledge in both those categories should be the aim, while later phases are more about proving the 1 Reliability, 2 Availability, 3 Maintainability, 4 Durability, 5 Public Acceptance, and 6 Final Stakeholder Objections.

In order to achieve the above goals the different types of pilots as defined in chapter 5 should be used for the different situations that will be encountered. RWS should allow the different types of PDP to overlap in order to achieve the best results (Mazzucato, 2014). Following, three of the Hellsmark et al. (2016) PDP types and their considerations are described that are most relevant for the RWS context.

Industrial-scale verification PDPs are of concern here as these are the type of pilots for which RWS is needed by the innovator. These are the pilots with the purpose of technological verification. It can be beneficial if RWS takes on the role of network manager in this type of pilots and the innovator simply takes on the role of as supplier (Hendry et al., 2010). Typical for this type of pilot is that it requires more funding than a private company budget permits.

Deployment pilot and demonstration plants are also of concern here, these aim to improve performance and reduce costs by gaining operating experience. This type of pilots gives access to users' knowhow and experiences. Here RWS mostly comes in as the location provider. These type of PDP involve high capital costs for the innovator.

Permanent test centers are used to address wider system issues and have the main aim of reducing technological risk. Due to the permanent character of the PDP it is fitted for continues improvements and testing new options. They are often used after deployment PDPs.

The final important responsibility of this team is to find and assign the PDP locations. It will be the responsibility of this team to stay in close contact with the project managers and the coordinating layer above them to keep an up to date overview of which projects have potential for which types of DPD. Direct contact with a potential Innovation strategists as well as with innovation areas would be in order.

8.6.1 Innovation Strategist

The PDP team needs to find PDP locations, these are projects that are on the planning and can integrate a PDP. Currently, it is a complicated process to find such a project that has the opportunity and is still in a phase of the project that it can be incorporated (Interviewee C, F).

It also often happens that innovation pop-up while working on a project and that the project that immediately functions as a pilot location. As there is no coordination, similar innovations are piloted in different projects.

Interviewee C suggests to assign an innovation strategist to every project RWS is taking on. This strategist could be the responsible within the IPM project management team to prevent both issues.

The strategists makes sure that when innovations pop-up, the innovation goes through the agreed standardized processes and evaluations to make sure that it is ready to be piloted and that RWS wants to cooperate in the pilot.

This strategist could also assess potential for PDPs in the project it works on and take the lead on incorporating the PDP that is matched with the project. This strategist could keep close contact with the innovation intermediary, the pilot team and the innovators and so ensures a smooth integrating of the PDP.

An additional advantage of these innovation strategists is that they can also ensure that projects are done with state of the art technologies as they are aware of all the innovations available and have an intrinsic motivation to implement them. In that way newly released technologies have greater chances of sales growth.

Interviewee C suggests to add this function to the IPM team in the form of an extra person, that works on a projects for 2 days a week. It could, however, from a financial perspective, as well as for an ease of implementation argument, better be that current IPM team members are all invited to do a crash course on innovation and PDPs. The ones applying show the intrinsic motivation to work with innovations. After the courses, the new rule will be that always at least one IPM team member needs to take on the innovation strategists role within the team and needs the certification from the course. In that way no extra employees are needed, tasks can be integrated, and the strategists already have experience in working on RWS projects.

8.6.2 Innovation areas

The current way of working is to incorporate PDPs in projects that are going to be undertaken. Another way of working would be to assign innovation areas. These areas will then be constantly used for DPDs. As one DPD is finished, the next one is incorporated in the same area. This is not possible for all kinds of innovations but for roads, guide rails, noise barriers, and more, this could be a fruitful solution. The area can be selected based on the use intensity of the infrastructure, the intrinsic motivation of the relevant asset manager, and many more suitability criteria. This would reduce lead times and costs as no suited project needs to be found and at the Innovation Area everything is already prepared for testing. An example would be an extra road lane with incumbent technologies that can be used in case of innovation down time. These innovation areas are most suitable for short-term PDPs that are earlier in the maturation process.

8.7 Procurement

Innovators are in need of Public Procurement for Innovation (PPI) so that they can actually start selling the innovations they developed to solve RWS' needs (N5). PPI has been proven to be a successful tool to obtain societally beneficial innovations from the commercial market (Aschhoff & Sofka, 2009). With regular procurement a tender is set in the market for a specific product or service that is available, with PPI a tender is set for a specific need with only functional requirements so that innovations that the procurer is not familiar with yet can be suggested (Edquist & Zabala-Iturriagagoitia, 2012). Another really important part of PPI is that tenders are set out in such a way that small and medium sized enterprises can compete (Edler & Georghiou, 2007). SMEs are currently not able to participate in tenders, it is even so that listed companies have to collaborate in a consortium in order to participate in tenders (McKinsey & Company, 2019)(Interviewee C). Commonly, tenders set out in the market are of a considerable size, in order to attract innovators to the market it is crucial to break the assignments into smaller chunks in order for SMEs to participate.

Interactive learning between organizations is an important predecessor for innovation and from that perspective, it is advised for procurers to work together with potential suppliers starting early on in the PPI process. Edler & Georghiou (2007) advise having focus groups early in the PPI process that involve policymakers, politicians, scientists from all kinds of disciplines, R&D, Marketing, management, and any others that could be relevant.

There is not yet consensus in the market about the solution directions for the societal challenges that RWS currently focuses on and it is therefore that Pre-commercial PPI (PCP) and "RWS as lead user" are the two procurement approaches that could be used (Uyarra et al., 2020). PCP can mitigate market uncertainty as well as technological uncertainty and RWS as lead user mitigates market uncertainty. Whether PCP or a lead user strategy is appropriate depends on the clearness of the societal problem and the readiness of the technologies.

8.7.1 Pre-Commercial Procurement (PCP)

One of the procurement types that RWS can use to obtain its set goals is PCP. PCP is the type of procurement that can be used when both the societal problems and potential solutions are unclear and more R&D, PDPs and other innovation efforts are still needed. The key aspect of Pre-Commercial Procurement is reducing market uncertainty by procuring a number of implementations before the innovation is completely developed, so that innovators know that their development costs will be followed by sales revenues (Aschhoff & Sofka, 2009). This type of PPI can be seen as a service contract, the more novel the innovation is, the easier it is to engage in this kind of service contract. Aschhoff & Sofka(2009) find empirical proof for the effectiveness of pre-commercial public procurement and specify that it might be specifically helpful for small firms with limited recourses.

A number of practical implications of PCP can assure the effectiveness of the procurement. For pre-commercial procurement to work tenders should be transparent, limited in size, and easily accessible, finally, they should have short and clear application processes, known by all potential candidates (Uyarra et al., 2020). In PPI it is important that the technical characteristics given are limited, as they limit the ability and creativity of potential suppliers. Only functional requirements that satisfy the public needs or solve social-cultural problems should be specified (Edler & Georghiou, 2007).

8.7.2 Lead User

The second procurement type that RWS can use is functioning as a lead user which is best used when the societal problem is well articulated and widely agreed on, but there is no clear solution available. RWS has sufficient purchasing power to constitute an entire lead market and can therefore serve as need-forecasters and believers in the technology (Beise & Cleff, 2004; Bleda & Chicot, 2020; von Hippel, 1986). It is critical for RWS to communicate clear needs by using performance specifications, to foster innovative solutions for those needs (Uyarra et al., 2020), emphasizing need N2: articulated needs.

In order to act as a lead user procurers should actively procure innovations. Without going into detail about the current tendering process, the basic problem with the current system is that winning a tender is still only dependent on traditional factors. The first step towards being a lead user is to incorporate the set goals, the focus points, into the tender requirements. Keeping updated lists with the state of the art technologies in the different fields should help procurers make sure that the criteria are up to date with the in the market available innovations, and challenges the innovators to come up with something even better to compete in the market (Interviewee P). The innovation intermediary updates the system of the procurers as soon as the innovation is moving to the commercialization phase. To achieve emission reduction goals for 2030 tenders should include specific metrics to encourage sustainable innovations. When procurers are up to date on what innovations have what emissions, they can set the criteria accordingly.

8.8 Design Evaluation

The in this chapter solutions are proposed to the defined needs of innovators. A focus group with RWS employees that are affected by this solution and RWS employees that are responsible for standardizing work processes was conducted to see if the solutions could fit in practice. Some important considerations came up, some resistance was brought to light and some additional functions were proposed. The evaluation is done per solution part.

8.8.1 Innovation Intermediary

The innovation intermediary is the topic, in the focus group, that brought up the most debate. The need for the function is not actively recognized by the participants. The implementation is debated too, the participants believe this solution to be unfeasible.

- One of the considerations for the innovation intermediary is the length of the innovation process. Focus group participants note that maturing an innovation generally takes years and that staying dedicated for the total duration could be a problem. More than a problem for this function, it is a confirmation that this function is needed. As this might not be a reachable goal for one single individual, it can be done by a function. When the person holding the office changes, a proper handover assures that the function is carried out continuously.
- One concern of the participants was the fear for an overload, especially in the earlier phases. Participants notice that there are hundreds of companies such as contractors, suppliers, start-ups, and data managers in the industry. Additionally, in the earlier phases of the innovation process still a lot of potential innovations are in their funnels.
  The seize of the industry is indeed considerably large. It is therefore that a large proportion of the efforts done by the innovation intermediaries are only taking place after the first RWS review moment. This prevents considerable amounts of innovation intermediary efforts being devoted to an innovation without a confirmed RWS interest in it. The innovation intermediaries efforts that take place before the RWS review moment are all related to informing the innovators what the criteria for the review moments are and thus contribute to matching the supply to the demand.
- The current situation, in which innovators ask their personal network of RWS employees until they find what they need, is not perceived as problematic by the participants. They consider it the innovator's own responsibility to learn about the RWS organization and find what they need. Something interviewee E deemed impossible, due to the size of RWS and the complexness of the processes. Contrasting to earlier statements regarding the industry being too big to cover with a group of innovation intermediaries, one states that in industry everyone knows each other. Another participant notes that it is a legit struggle for innovators to know where to go with their innovation. One of the participants does not understand where the need for organized contact with the stakeholders comes from, innovators should just be able to talk to them. Later in the session one participant gives an example, in a different context, that is perceived as problematic, in which an innovator asked all asset

managers with a certain type of structure in their portfolio if he could pilot his innovation on their structure.

- Using a personal network to randomly ask for favors is problematic for innovators as it costs time and is highly uncertain, but it is even more problematic for RWS as it costs resources to handle all of these random requests. More importantly there is no central coordination on, not even awareness about, of what innovation are worked on and which are not. The innovation intermediary prevents these kinds of situations.
- Participants suggest to have these innovation intermediaries per articulated RWS goal instead of per bundle of companies. There is a believe that innovations that do not directly attribute to one of the goals do not deserve attention. RWS already has an organizational structure revolving around these goals and the innovation intermediaries could fit in their hierarchy. This could be a plausible solution if the innovation intermediary would be a single solution. The teams concerned with the RWS goals are concerned with WHAT kind of innovations are needed. Organizing a separate process for each of the goals would disregard possibilities for standardization, learning and coordination. It could also be really hard to classify a certain innovation as part of one of the goals specifically, they could tackle more than one goal at the same time. Implementing this structure would again allow for situations in which innovators just try somewhere else until they find one willing to participate.

8.8.2 Review Committee

The three main topics of interest regarding the review committee in this focus group are; financing, the members of the committee, and the level of hierarchy that is needed to be included in decisions.

- First, the committee should include those who own the resources, this focus group shows that it can be various types of owners that own the financial resources. Most of the goal teams have financial recourses to spend on achieving their goal. Also, a variety of other initiatives have been assigned a budget.
- Second, the focus group agrees on the committee members. The need for the committee to be multi-disciplinary, for the committee to include specific field experts, and employees from the goal teams that the innovation applies to.
- Third, a variety of opinions surround the level of hierarchy needed to be on the team. Some think that it is better to mostly have committee members from practice, others think it is important to include high level managers. No consensus was achieved.

8.8.3 Change & Stakeholder Management

When it comes to managing change and the involved stakeholders, participants want to add two possible approaches that they think could work. The change team could take them into account.

- First, participants stress that it is important to find the early adaptors and use them to convince the other stakeholders about the innovation. They recommend to find early adopters that are field experts so that they have a power to convince.
- Second, participants propose and discuss a comply or explain methodology. Just tell employees we changed something for the better and make them use the new product or procedure. If they do not comply, make them come and explain their selves at higher management.

8.8.4 PDP

In the category of PDPs, participants are concerned with three topics. The first is the question about who should initiate these PDPs. The second is about convincing people to participate in a PDP. Third, is about finding PDP locations.

- One participant questions who is or should be the initiator of these PDPs, but there is no clear answer. It is RWS that wants to see PDP results before procuring the innovation, but it is the innovator who wants to do a PDP to show RWS their innovation to convince them to procure it. Figure 17 shows that the PDP needs both the RWS review committee and the innovator's review committee to move the innovation into the PDP phase of maturation. Concluding, it is the innovator who tells the innovation intermediary that they have completed the previous phase and are ready to face the review committee and ask to move on to the next phase, the PDP phase.
- Participants stress that it is of utmost importance that those who are involved in the PDP have to be convinced of the benefits of the innovation in order to make them participate actively.
- One participant states that it is not problematic to find a PDP location in the current situation if the innovation contributes to a shared goal. Then, the innovator has to find a project that has no time pressure, a budget ánd employees with a positive mindset. This is exactly the reason that innovators need help to find a PDP location. In the first place to find a project and in the second place to make sure that projects that are going to happen become more flexible in order to create space for PDPs.

8.8.5 PPI

With regards to PPI, participants again bring up the comply or explain methodology. Higher management just has to change the criteria for procurements and then procurement employees have to do the procurement in the new way. This topic has, however, not been thoroughly discussed in the focus group

8.8.6 Idea to Launch System (Management)

Next to the focus group, some interviews already had a reviewing character, most of these interviews with higher level managers. These managers were questioned about the structuring of the system as a whole and the way innovation could be managed.

- Interesting are the findings from the interview with higher level management interviewee T. Interviewee T believes in setting clear goals, sticking to innovations that contribute to those goals. Interviewee T is explicitly not willing to let go of the Innovate-Uniform-Produce mantra. It is therefore that she believes that any designed innovation process should be subsections of the "Innovate" part. Only after which RWS is going to "Uniform" their processes and then start to "Produce" by which procurement is meant.
- Interviewee S stressed that it would not be feasible to have a designated department for innovation. Where interviewee R and T believe that if a department had to be appointed as the responsible for innovation it should be WVL.

9 Limitations and further research

The findings and their reliability and fit is influenced by the sample population used. The original intention was for the sample to be representative for the organization and the industry, but this was difficult in practice, more so given the 'work from home' conditions due to the COVID-19 pandemic.

The first problem was that it was difficult for RWS employees to refer me to an innovator. They could not do so because they either did not know any innovators or had such an ambiguous relationship with them that they did not dare to put on any other strains.

Second, the findings are also skewed because the sample population mostly consists of RWS employees that are intrinsically motivated to innovate. Finding the more conservative colleagues was hard as interviewees generally did not point out more conservative colleagues and those who were pointed out refused to make time for an interview.

Third, taking into account that RWS has over 9000 employees in many different departments and that there are hundreds of companies in the industry, the time span of this research did not allow to create a representative sample population in the first place as the diversity among them was too broad to catch in a couple of dozen interviews. Entire RWS departments are missing from the sample population, including departments that are involved in innovation.

A final limitation in this category is that this study was conducted online due to the Covid-19 pandemic. Communication mostly took place by MS Teams, Zoom, and other digital options. This influences the contact that took place with interviewees and other people of interest. The lack of the possibility to walk by someone's desk to ask a quick question or to stress that I still expect a response to an email, slowed down the process.

One of the evaluation criteria for Grounded Theory research concerns the question whether the proposed recommendations will work. The focus group gathered a variety of improvements, suggestions and unresolved problems. The problem statement concerned many different departments, initiatives, and employees, it was impossible to acquire the knowledge on how to implement everything in to detail.

Reliability is one important quality measure in doing research. One of the categories that can affect the reliability is the researcher. Even though the aim was to be object, full objectivity is unreachable. The qualitative nature of this study left room for interpretations influenced by the view of the researcher.

Now that this thesis has shown the different types of uncertainty that are relevant for the RWS context, determined the needs innovators have in relation to those uncertainties and developed a solution for those needs, multiple different future studies can add on this work and aim to foster innovations that can contribute to the goals set by RWS.

This study was so broad, included so many different departments and aspects of the innovation process, that it would be beneficial to now conduct a specific research about each and every separate aspect in the specific context. Figure 17 might be used as a starting point to contact the relevant stakeholders at each point of the innovation process.

First, RWS would benefit from more practical and specific knowledge on how to conduct PDPs and on how to implement PPI. It is recommended for RWS to conduct research into the PDP and PPI practices of neighboring countries' comparable ministries. Then, continuous case studies and comparative studies should ensure that RWS continuously works towards an optimal implementation.

Secondly, RWS would benefit from research into the behavior and culture of their own employees and managers. It could significantly help the change and stakeholder management if there is more knowledge about their behavior, culture, and soft institutions.

Finally, if solutions that are proposed in this research are implemented it would be recommended to conduct studies on their actual achievements. Limitations, additions and enhancements can then be formulated in an iterative process.

10 Conclusion

RWS experiences problems with maturing innovations in the industry that are needed for their set goals. This grounded theory research was conducted in order to identify and analyze the problem, and design recommendations. After exploratory conversations the problem was specified to uncertainties that are inherent to innovation, but hinder their maturation. The following research question was constructed after the problem analysis: *How can RWS mitigate uncertainties inherent to innovations in the infrastructure industry?*

First, different types of uncertainty were identified from literature. After which the empirical data clarified which uncertainties are important in the RWS context and in what way they are manifested. Technological uncertainty, market uncertainty, management uncertainty, socio political uncertainty, regulatory uncertainty and time uncertainty are the six main categories of uncertainty that are affecting innovations.

Secondly, a literature review on the topic of public policy was conducted. An overview of possible innovation policies gives a clear insight in what kind of tools RWS could use to foster innovations. Policies that could be implemented by RWS can be categorized as policies that affect the demand of innovations and policies that affect the supply of innovations. The category of demand side policies comprises of systemic policies, regulations, public procurement and support of private demand. The category of supply side policies comprises of R&D subsidies, supporting universities and public research, and Pilot and demonstration plants.

Third, from interviews and observations an overview of the different procedures in place at RWS to mitigate uncertainty was constructed. The procedures in place depend on the situation the innovation was created in. Innovations could be technology push, market (RWS) pull, and push-pull. This overview shows that RWS has implemented different types of innovation policy, such as the Innovation Agenda, the Innovation Loket and the Innovation Test Centre.

Fourth, a needs assessment was conducted. Needs with regards to mitigating uncertainty were collected with interviews and observations. These needs are summarized in table 9. This overview of needs should be taken into account in future innovation efforts at RWS. The overview is the basis for the proposed innovation process.

Finally, a newly designed innovation process is proposed based on all the previously elaborated findings (Figure 17). This process relies on different teams with different expertise that are coordinated by the innovation coordinator. The innovations that come into this system are coordinated by a innovation intermediary. Along this innovation process, innovators benefit from different types of innovation policy such as systemic policies, regulation qualification policies, PDPs and PPI.

Concluding, this research has led to an advice regarding the installation of a variety of teams and a standardized process. The practical details are open to be fitted to the wishes of the different stakeholders, but the aggregated process is practical and implementable. The answer to the question "How can RWS mitigate uncertainties inherent to innovations in the infrastructure industry?" is that RWS needs to provide a structures process composed of the different innovation policies. The designed process should be this structured process in which the efforts of RWS are aligned with those of the innovator to achieve a synthesis of efforts.

The different parts of the solution could be summarized in four main types of innovation policy and stakeholder and change management. RWS should be implementing innovation intermediaries. RWS should be implementing clear qualification methods for all kinds of innovations. RWS should be implementing different types of pilot and demonstration plants. In conducting those PDPs all stakeholders should agree on the assessment criteria before starting. RWS should start procuring what is in line with their communicated needs, correctly implementing PPI will enable RWS to do so. Before dedicating resources to either of these policies the dedicated review committee should evaluate the innovation and make a decision to do so or not. RWS should have an ongoing process of managing stakeholders and the change they experience.

11 Appendix A: Interviewee Overview

Letter	Organization	Department	Expertise/Function
A	RWS	ITC	Manager
B	RWS	GPO	InnovA58
C	RWS	GPO	Technical Manager
D	RWS	VWM	Smart Mobility
E	RWS	WVL	CIP
F	RWS	GPO	Innovation & Market
G	RWS	GPO	Technical Advisor
H	Path2Mobility		Owner
I	RWS	GPO	Innovation & Market
J	Royal HaskoningDHV		System Development
K	Heijmans		Innovation Manager
L	Beton Ballon		Owner
M	RWS	CIV	Digi-Campus
N	RWS	CIV	Digi-Campus
O	RWS	CIV	Digi-Campus
P	Dura Vermeer		Innovation Manager
Q	Nebest		Product Development Manager
R	RWS	WVL	Manager
S	RWS	Vital Infrastructure Industry Program	Manager
T	RWS	Board	Manager

12 Appendix B: Code Book

Higher Order	Middle Order	Contextual/Lower Order	
Technological Uncertainty			
	Functioning		
		Side-Effects	
		Life-Cycle	
	Developement		
		Integration	
	Use		
		User	
		User Adaption	
Market Uncertainty			
	Customer Needs		
		Articulation	
		Organizational Dissonance	
		Legitimacy	
		BestuursAkkoord	
		Procurement	
Management Uncertainty			
	Management Activities		
		Ambidexterity	
		Top-Down vs. Bottm-Up	
		Information and Knowledge Management	
		Authority	
		Resposibility	
			Network
			Intrapreneur
		Change Management	
		Performance Managment	
	Metrics to Support Desiscion Making		
	Business Model		
		ROI	
Social/Political Uncertainty			
	Diverse Interests		

		Conflicting Internal Interests	
		Stake Holder Involvement	
	Complicated Private/Public Relations		
		Complicated Relationships	
Regulation			
	Rule Content	Rules	
	Final Complience	Employee Interpretations	
	Qualification Method	GPO Technical Experts	
Time			
	Temporal Complexity		
	Interconnectedness with Other Uncertainty		
		Lead Times	
		Timing	
Situations			
		General Procedures	
		Technology Push	
		Market Pull	
		Push-Pull	
		Ulterior Motives	
Innovation Goals			
		Problem Solving	
		Ambition Obtaining	
Stage-Gate			
Culture			
		NIMBY	
		NIH	
		Fear for Failure	
		HR	
		Leadership	
		Daily Work Changes	
Procedures Technology Uncertainty			
		Finance Testing	
		Modelling	
		Test Locations	
		CIP	

		PDP	
Procedures Market Uncertainty			
		DBFM	
		PPI	
		Innovatie Agenda	
		2-phased Contracts	
		Innovation Loket	
		Innovation Challange	
Procedures Management and Social Political Uncertainty			
		Innovation Strategist	
		Innovation intermediarys	
		Desicion Makers	
		Stakeholder Management	
		Structured Process	
Procedures Regulatory Uncertainty			
		ITC	
		GPO Technical Experts	

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