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GRADUATION THESIS

DEVELOPING A DECISION-MAKING FRAMEWORK TO DEAL WITH MR&R COMPLEXITIES IN A FIT-FOR-PURPOSE MANNER

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DEVELOPING A DECISION-MAKING FRAMEWORK TO DEAL WITH MR&R COMPLEXITIES IN A FIT-FOR-PURPOSE MANNER

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PREFACE

After a full year of master courses, an internship at a contractor and a multidisciplinary project in Indonesia, I had to come up with a topic for my graduation thesis. During my internship, it was my former manager Alexander who introduced me to the current renewal and replacement challenge of Rijkswaterstaat. The challenge immediately attracted me due to the magnitude and diversity of the challenge. After I gathered more information, the followed procedure to deal with this challenge raised some questions with me. Despite the size of the challenge and the corresponding conditions among the soon-to-be outdated asset, every bridge, tunnel or lock was managed individually. But, what about the opportunities to look beyond the borders on a single asset? Is it that hard to find these interfaces, or is there more to it? I decided that I wanted to know more about the underlying causes and investigate potential options to find asset transcending benefits.

And here we are, months, interviews, meetings and a validation session later, I finished my research. While looking back at the graduation process, I can say that I am really proud to finish my studies this way. I took a leap in faith and tried to gather all the ins and outs of the relatively new renewal and replacement challenges. I have to admit that the diversity of the challenge, which goes way beyond the conditions of the assets, also caused me some trouble in finding an appropriate way to focus my research.

Luckily, I had the opportunity to be supervised and assisted by a great graduation committee. First of all, Yke. I want to thank you for your guidance and ability to show me the importance of seeing the bigger picture in my research. Marleen, Leon warned me for your critical view in advance. However, this did not withhold me to pick you as my chair and I do not regret it either. With your ability to see things through and put the finger on the sore spot, you really helped me in demarcating and specifying my research. Martijn, whenever I had a question, I could always come to you and you put a lot of effort in reading and discussing my work with me. Besides that, I want to thank you a lot for your guidance and ability to mirror your expertise on my research topic. Leon, with your positivity and opportunity to see problems from different angles, you helped me a lot throughout my research. At times when I was not sure about the direction and progress of my research, you comforted me which I deeply appreciate.

Next to my committee members, I want to thank Ivo and Roy of the Municipality of Amsterdam. You allowed me to get a 'look behind the scenes' of the Municipality. As icing on the cake, you invited me to speak on a knowledge sharing event where I was able to present and validate my findings.

On a personal note, I want to thank my family, friends and in particular my lovely girlfriend Inelotte. I deeply appreciate your unconditional patience, love and support throughout my thesis. Despite the fact that simultaneously working on our theses sometimes led to tense and difficult situations, I am glad we managed it this good and cannot wait to celebrate the end of our studies under a palm tree with a coconut in our hands.

To everyone who reads this, I really hope you enjoy reading my graduation thesis as much as I did.

Misiu Smits
Rotterdam, April 2020

SUMMARY

Historical developments and innovations in the field of civil engineering contributed to the state-of-the-art structures that shape our transportation infrastructure network nowadays. By way of contrast, solving the mobility issues of the past, created a challenge in terms of conservation today as many assets are reaching the end of their technical, economical and functional lifetime [Hertogh et al., 2018]. Main challenge arises for public authorities which have to meet safety demands and satisfy user expectations in the context of aging assets, imperfect knowledge on their conditions, limited resources, increasing traffic volumes and threats from climate change. Determining when, what and how has to happen is therefore more complex than simply renewing or replacing assets [Polder et al., 2012; van der Vlist et al., 2015; Nicolai et al., 2016].

Together with the evident challenges, the magnitude of the predicted increase of Maintenance, Renewal and Replacement (read: MR&R) projects creates a variety of opportunities. One of the opportunities, is to widen the perspective beyond the boundaries of a single asset. Creation of a holistic view and recognition of portfolio opportunities is considered to be key in realizing strategic and tactical objectives, improved alignment with other projects and realize savings due to a decreased need of resources and selection and procurement procedures [Ferns, 1991; Heising, 2012; Chen et al., 2013].

Realizing the potential while controlling the present challenges is however easier said than done. Public organizations within the Netherlands are currently facing serious difficulties in the implementation of their MR&R projects in a fit-for-purpose manner. Fit-for-purpose, in this sense, refers to choosing the best solution for a problem, given the others alternatives [Koops et al., 2017]. In order to investigate both the complexities and the possibilities of MR&R challenges, the main questions of this research is:

"How can decision-making on the MR&R interventions of the emerging set of soon-to-be outdated assets be supported to configure assets in a fit-for-purpose manner?"

Since the preferred solution regarding the development of a project is picked during the front-end development (read: FED) of a project, the research is focused on these preparatory phases. During the FED, the problems are assessed, a preferred alternative given the present requirements is selected and further defined before it continues to the consecutive project phases [Weijde, 2008]. To provide support on the related decision-making process, the research is guided by two main deliverables:

1. Provide an overview of the main complexities of MR&R challenges which influence the FED process
2. Develop a framework to support public organization in organizing their FED process to deal with their emerging amount of aging assets in a fit-for-purpose manner

The overview of the main complexities public organization face during the FED of their to MR&R challenge was created by a combination of scientific and empirical research. Given the present body of knowledge on MR&R challenges, FED and decision-making complexities, a conceptual framework was created. This functioned as a pair of glasses through which multiple cases were analyzed. By investigating four MR&R cases of Rijkswaterstaat, the Municipality of Amsterdam and the Province of North-Holland individually and jointly, a set of 20 challenges emerged. Altogether, these challenges influenced the opportunity of public organizations in the creation of fit-for-purpose project, portfolio or program configurations during the FED procedure.

To create a framework which indicates how to deal with these challenges, seven decision-making dilemmas were identified as presented in figure 0.1. These dilemmas indicate the opportunities executive authorities within public organizations have in aligning their FED process to their perceived complexities, requirements and resources. The red cluster marks the dilemmas which influence the physical solution space of MR&R challenges, whereas the dilemmas in the orange cluster determine the design

of the FED procedure. Since the opportunity to review and revise made decisions applies on both contextual and procedural dilemmas, the agility dilemmas is present in both clusters.

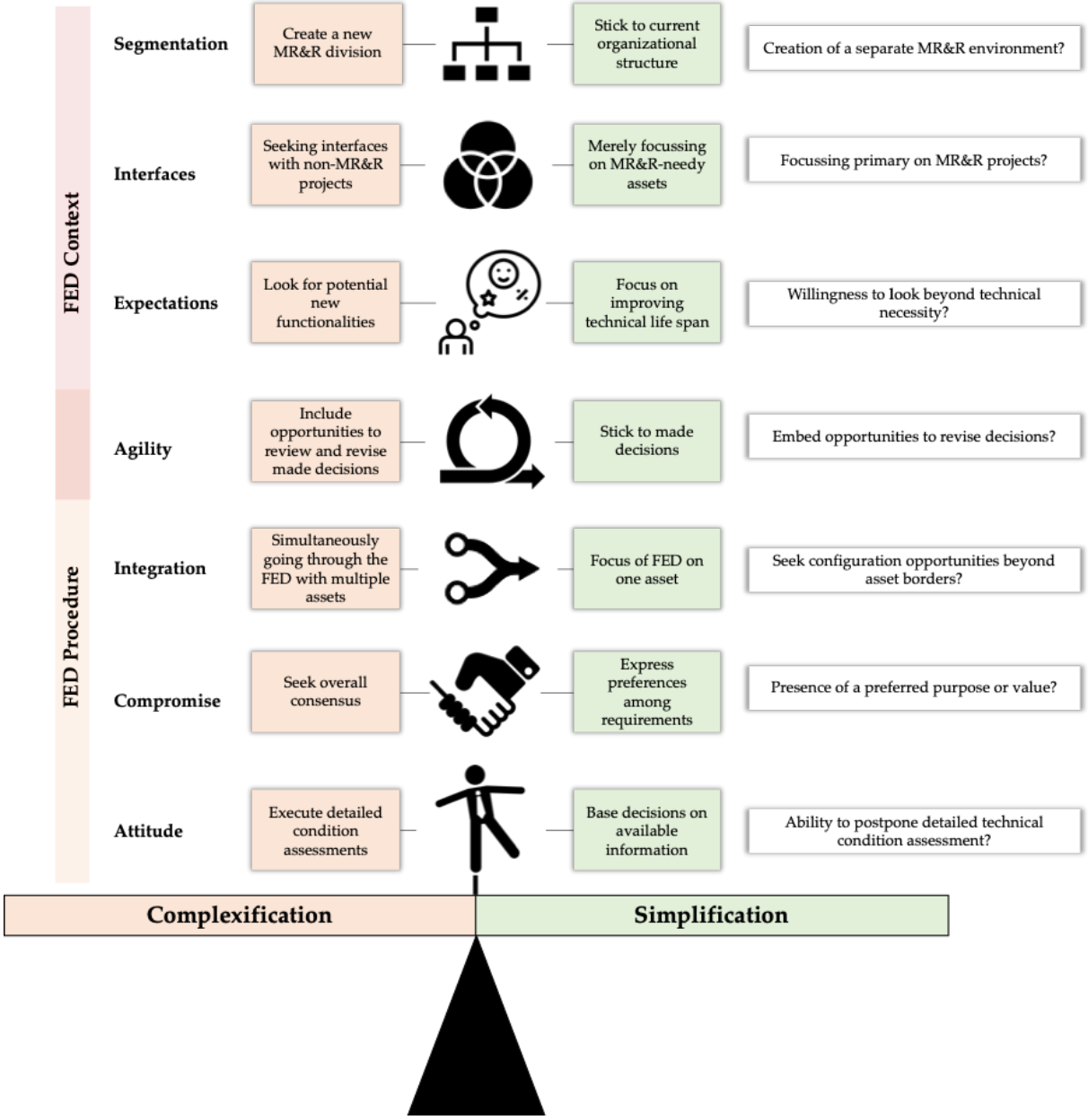

Figure 0.1: Overview of the decision-making framework

In the end, public organizations in charge simply have two choices: simplification or complexification of the FED process. To deal with the emerging set of soon-to-be outdated assets, the process may be kept simple and foreseeable, but the opportunity to create asset transcending benefits is small. On the other side, an organization may decide to deliberately complicate the configuration process by increasing the amount of elements and related considerations. Given the developed decision-making framework, there are seven options to realize potential integrated benefits. during the FED procedure. With every dilemma, decisions to either simplify or complicate the FED process may be made, which create the opportunity for a public authority to adjust the configuration process to the present requirements, complexities and resources.

Observance of the cases and the afterwards validation of the framework however pinpointed the risks of increasing the complexity of the FED process. For example, creation of a separate program and

related procedures to deal with the MR&R challenge may result in a reluctant attitude of the involved staff and create an unforeseen amount of interrelations with other divisions in the organizations. If the amount of components and actors involved in the decision-making process increases, also a greater span of control is demanded [Leijten, 2017]. Manageability issues due to the increase levels of complexity may therefore hamper the overall FED process. Therefore, using the developed framework should help decision-makers in public organizations in finding a balance between the potential to create certain benefits and the risk of making the process too complex.

In order to improve the validity of the developed decision-making framework, it was first tested in an existing case of Rijkswaterstaat by conducting an imitation experiment. Based on the conditions of the case, decisions on the dilemmas in the framework were made and translated into a FED process. Next to the imitation experiment, an expert review on the framework was conducted. In the presence of representatives of the Municipality of Amsterdam and Rijkswaterstaat, the framework was tested on its completeness, functioning and usability. In the end, both validation incentives confirmed the added value of the decision-making framework as it provides the opportunity for public organizations to align their MR&R challenge and objectives with a FED process design.

SAMENVATTING

Historische ontwikkelingen en innovaties op het gebied van civiele techniek hebben bijgedragen aan het hoogwaardige infrastructuur netwerk dat Nederland vandaag de dag kent. Waar in het verleden voornamelijk mobiliteitsproblemen de uitdaging binnen de infrastructurele sector waren, staat deze vandaag de dag voor de bijkomende opgave de bestaande infrastructuur in stand te houden. De assets die gezamenlijk het hoogwaardige netwerk vormen komen namelijk aan het einde van hun technische, economische en functionele levensduur [Hertogh et al., 2018]. De vervanging en renovatie van deze assets is complex voor de publieke autoriteiten, aangezien er aan de veiligheidseisen voldaan moet worden terwijl gelijktijdig de behoeften van gebruikers bevredigd dienen te worden. Dit speelt zich daarnaast af binnen de context van verouderende assets, onvolledige informatievoorziening betreffende de staat, beperkte middelen, toenemende gebruikersaantallen en bedreigingen als gevolg van klimaatverandering gerealiseerd te worden. Bepalen wanneer, hoe en wat er moet gebeuren is daardoor complexer dan simpelweg een asset vernieuwen of vervangen [Polder et al., 2012; van der Vlist et al., 2015; Nicolai et al., 2016].

Gezamenlijk met de evidente uitdagingen zorgt de omvang van de Onderhoud-, Vernieuwing- en Vervaning- (Engels: Maintenance, Renewal & Replacement, afgekort: MR&R) projecten voor een variëteit aan kansen. Één van deze kansen is gerelateerd aan de mogelijkheid om verder te kijken dan een enkele asset en daarmee de oplossingsruimte te vergroten. Het ontwikkelen van een holistische blik en herkenning van portfolio-mogelijkheden worden gezien als essentieel in het realiseren van zowel strategische- als tactische doeleinden, verbeterde afstemming met andere projecten en het verminderen van de uitgaven vanwege een gereduceerde totale behoefte aan middelen en selectie- en aanbestedings procedures [Ferns, 1991; Heising, 2012; Chen et al., 2013].

Het benutten van de aanwezige kansen en gelijktijdig de aanwezige uitdagingen in controle houden is echter makkelijker gezegd dan gedaan. Publieke opdrachtgevers in Nederland ondervinden serieuze uitdagingen in de implementatie van hun MR&R opgaven op een passende manier. Passend, in deze context, refereert aan de keuze voor de beste oplossing voor een probleem, gegeven alle andere alternatieven [Koops et al., 2017]. Om zowel de uitdagingen als de kansen van MR&R opgaven te onderzoeken, is de volgende hoofdvraag geformuleerd:

Hoe kan de besluitvorming omtrent het vervangen of renoveren van een groeiend aantal verouderde assets ondersteund worden om zo de configuratie van de assets op een passende manier uit te voeren?

Aangezien het voorkeursbesluit betreffende de ontwikkeling van een project wordt genomen aan het einde van de front-end development (verkenningsfase van een project, afgekort: FED), is het onderzoek gericht op deze voorbereidende fasen. Gedurende de FED worden de uitdagingen in kaart gebracht en mogelijke oplossingen geconfigureerd. Daarna wordt er een voorkeursbesluit genomen op basis van de aanwezige vereisten en vervolgens wordt dit verder uitgewerkt voordat het project verder gaat naar de daar op volgende projectfasen [Weijde, 2008]. Om dit proces te ondersteunen, is het onderzoek opgesplitst in twee hoofdaspecten:

1. Creëren van een overzicht van de voornaamste uitdagingen die zich voordoen tijdens de FED van MR&R opgaven
2. Ontwikkelen van een framework om publieke opdrachtgevers te ondersteunen in het organiseren van hun FED-proces, om op een passende manier om te kunnen omgaan met het groeiende aantal verouderde assets

Het overzicht van de voornaamste uitdagingen die publieke opdrachtgevers tegenkomen tijdens de FED van hun MR&R opgaven, is ontstaan uit een combinatie van wetenschappelijke literatuur en empirisch onderzoek. Gebaseerd op de huidige kennis omtrent MR&R opgaven, FED en uitdagingen omtrent besluitvorming is er een conceptueel framework opgesteld. Dit framework heeft gefungeerd

als een bril waardoor meerdere MR&R opgaven geanalyseerd zijn. Door vier verschillende MR&R opgaven van Rijkswaterstaat, de Gemeente Amsterdam en de Provincie Noord-Holland zowel individueel als gezamenlijk te onderzoeken, is een set van 20 uitdagingen opgesteld. Gezamenlijk beïnvloedden deze uitdagingen de mogelijkheden van publieke opdrachtgevers om passende project, portfolio- of programma-configuraties te maken tijdens de FED.

Met deze uitdagingen als startpunt, is het framework in figuur 0.2 opgesteld. Hierin worden zeven afwegingen omtrent de indeling van het FED-proces worden weergegeven. Deze dilemma's laten de mogelijkheden zien die bevoegde autoriteiten binnen uitvoerende organisaties hebben in het aanpassen van het FED-proces op basis van de aanwezige uitdagingen, vereisten en middelen. Het rode cluster markeert de dilemma's die de fysieke oplossingsruimte van een MR&R opgave beïnvloeden (welke assets en afwegingen worden wel of niet meegenomen?), terwijl de dilemma's in het oranje cluster de indeling van het FED-proces bepalen (wanneer, hoe en op welke schaal worden besluiten genomen?). Aangezien de mogelijkheid om gemaakte besluiten te heroverwegen en te herzien zich voordoet in zowel contextuele als procedurele dilemma's, is het adaptiviteits dilemma aanwezig in beide clusters.

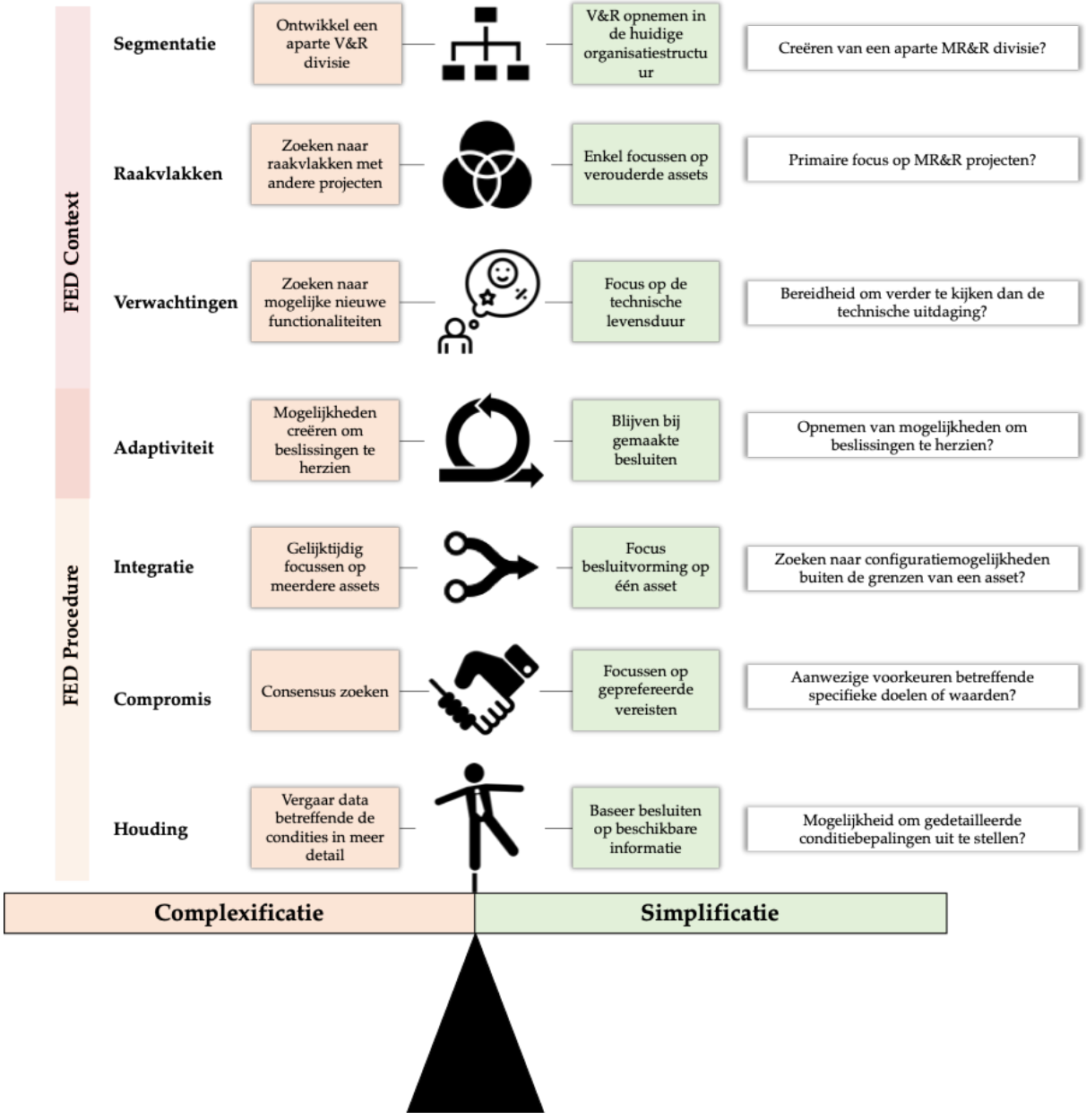

Figure 0.2: Overzicht van het besluitvormingsframework

Kort samengevat komt het er op neer dat publieke opdrachtgevers twee mogelijkheden hebben: simplificatie of complexificatie van het FED-proces. Omgaan met een groeiend aantal verouderde assets kan gedaan worden door het FED-proces simpel en overzichtelijk te houden. Assets doorlopen de FED in geringe interactie met andere assets. Hiermee is de kans op asset oversteigende voordelen echter klein. Aan de andere kant kan een organisatie er bewust voor kiezen om het configuratieproces te compliceren, door het aantal elementen en gerelateerde interrelaties te doen toenemen. Het ontwikkelde besluitvormingsframework laat zeven mogelijkheden zien om mogelijke kansen binnen een MR&R opgave te benutten tijdens het FED-proces. Door bij elke afweging de keuze te hebben tussen enerzijds simplificatie en anderszijds complexificatie, kan een publieke organisatie haar FED-proces op verschillende manieren aanpassen aan de huidige situatie.

Observatie van de verschillende MR&R opgaven en de validatie van het framework hebben echter ook de risico's van complexificatie van het FED-proces laten zien. Het opzetten van een apart programma met bijbehorende nieuwe werkmethoden om de MR&R opgave aan te pakken kan bijvoorbeeld ook resulteren in een terughoudende houding van het personeel en in een onvoorzien aantal interrelaties creëeren met andere divisies binnen de organisatie. Indien het aantal componenten en belanghebbenden die betrokken zijn bij het besluitvormingsproces toeneemt, is er ook een grotere 'span of control' nodig [Leijten, 2017]. Beheersbaarheidsproblemen door toenemende complexiteit van het besluitvormingsproces kunnen daarmee het gehele FED-proces vertragen. Derhalve kan het gebruik van het framework publieke opdrachtgevers helpen in het vinden van een balans tussen de potentie om bepaalde voordelen te behalen en de risico's die verbonden zijn aan het té complex maken van een FED-proces.

Om de validiteit van het ontwikkelde besluitvormingsframework te verbeteren, is deze getest in een bestaande Rijkswaterstaat opgave. Dit is gedaan door middel van een imitatie experiment. Gebaseerd op de karakteristieken van de bestaande opgave zijn er antwoorden geformuleerd op de afwegingen in het ontwikkelde framework. Op basis van deze antwoorden op de dilemma's is er een vertaling gemaakt naar een FED-procedure, om zo de bruikbaarheid van het framework in bestaande situaties te toetsen. Naast het imitatie-experiment is er een expertsessie georganiseerd om de validiteit van het framework verder te vergroten. In de aanwezigheid van afgevaardigden van de Gemeente Amsterdam en Rijkswaterstaat is het framework getest op volledigheid, functionaliteit en bruikbaarheid. Uiteindelijk hebben beide validatie initatieven de toegevoegde waarde van het besluitvormingsframework bevestigd, aangezien het publieke opdrachtgevers de mogelijkheid geeft om hun MR&R opgave en bijbehorende doelen af te stemmen op het FED-proces.

ACRONYMS

- **EMVI** - Economically Most Advantageous Tender (Dutch: Economisch Meest Voordelige Inschrijving)
- **FED** - Front-end development
- **GBC** - Regional maintenance contract (Dutch: Gebiedscontract)
- **GHG** - Green House Gas
- **HVWN** - Main Waterway Network (Dutch: Hoofd Vaarwegen Netwerk)
- **HWN** - Main Road Network (Dutch: Hoofd Wegen Netwerk)
- **HWS** - Main Water Systems (Dutch: Hoofd Water Systemen)
- **IPM** - Integrated Project Team
- **KARGO** - Large-scale maintenance of steel bridges over the Amsterdam-Rhine Canal (Dutch: Kunstwerken Amsterdam-Rijnkanaal Groot-Onderhoud)
- **MR&R** - Maintenance, Renewal and Replacement
- **PBK** - Program Bridges and Quay Walls (Dutch: Programma Bruggen en Kademuren)
- **PMO** - Provincial Multi-annual Maintenance Program (Dutch: Provincial Multi-Annual Maintenance Program)
- **PNH** - Province of North-Holland
- **PPP** - Public Private Partnership
- **SLA** - Service Level Agreement
- **RWS** - Rijkswaterstaat
- **VenR** - Vervanging en Renovatie

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1 INTRODUCTION

The never ending story of aging. While we as human beings are looking for solutions to stop this evolutionary process, options to prolong life expectancy are investigated in a range of industries. Every sector has to deal with it, though the approaches might differ. All of the fascinating structures designed and built by civil engineers will be outmoded one day. What if technology is not capable to keep up with the destructive temper of mother nature? Should we admit to the status quo or fight this never ending process? May there be other reasons why we are constantly caught up by reality? Perhaps the cause and solutions for this problem lie by ourselves. By investigating this process, we might get a little closer to finding convenient answers. At least, if we want to.

According to the Global Competitiveness Report of the World Economic Forum, the Netherlands currently has the best transportation network in Europe [Schwab et al., 2018]. Every day, thousands of bicycles, vehicles, trains and vessels use the extensive infrastructure facilities, which makes it a vital part of the Dutch economy [Hijdra et al., 2015]. Obviously, as a derivative from the famous expression of playwright John Heywood (1563): "Rome wasn't built in a day" [Henderson, 1999], it took an immense effort to create the present-day transportation network. Synchronous to the nation wide reconstruction after the Second World War, grand investments in transportation infrastructure were made. Bridges, roads and rail tracks popped out of the ground like mushrooms and built up the infrastructure network as we know it today. However, awareness and understanding regarding the durability of civil structures back in the days was less comprehensive than today [Polder et al., 2012]. Decades later, an increasing challenge develops while these assets are reaching their technical end-of-lifetime. As a consequence of the baby boom in asset construction around the 1960s and 1970s, the forthcoming decades will largely be about maintaining, renewing and replacing aging assets [Hertogh et al., 2018].

Public organizations now have to find appropriate solutions to deal with this new type of activities, next to their existing operations. Compared to newly built projects (i.e. greenfield projects which lack constraints by imposed by prior work), these Maintenance, Renewal and Replacement (read: MR&R) projects (i.e. brownfield projects which encompass a modification or upgrade of an existing asset) are considered more complex due to their tangible and intangible linkages with existing systems [Bosch-Rekveldt, 2011]. Given these interdependencies, configuration of MR&R projects is considered a complex challenge public authorities will be facing to a larger extent in the nearby future [van der Vlist et al., 2015; Hendricks et al., 2018]. By configuration of MR&R projects is meant the process of selecting soon-to-be-outdated assets to be part of a project. Important note should be made, that the size of a project can differ from one asset to a pre-selected set of assets which all need to be maintained, renewed or replaced. According to Platje and Seidel [1993]; Martinsuo and Lehtonen [2007]; Pellegrinelli [2011], projects within an organization which are connected through interests, priorities and resource dependencies could be suitable to configure as a certain project portfolio, consisting of multiple projects. Additionally, Elonen and Artto [2003]; Dammer and Georg [2006] state that a shift from the management of a single project towards a multitude of projects will be necessary for effective and efficient overarching developments within organizations. With an upcoming challenge of aging assets, public organizations are seeking new methods to embed these MR&R projects into their existing operations.

By way of example, Rijkswaterstaat currently faces a large-scale MR&R challenge called the: 'Vervanging en Renovatie Opvave' (freely translated: Replacement and Renewal Challenge). Despite the magnitude of their challenge and the present similarities among the assets, configuration seems to take place on an one-asset-one-project basis. Absence of a holistic view on the multitude of projects and recognition of portfolio opportunities influences the chance to achieve sustainable success [Milosevic et al., 2009; Heising, 2012]. Looking beyond the boundaries of a single asset may create outcomes which would not be achieved by execution of one-asset-one-project kind of projects [Shehu and Akin-

toye, 2009; Rijke et al., 2014]. Examples of potential advantages of managing multiple projects within one overarching program are: realisation of strategic and tactical benefits and savings due to the reduced need of (staff) resources, selection and procurement procedures [Ferns, 1991; Pellegrinelli et al., 2007; Chen et al., 2013].

Options to configure MR&R projects are numerous, but given the amount of assets with varying conditions, internal and external interdependencies, limited amount of available resources (people, finance, time etc.) and additional public organizational requirements, decisions regarding the configuration are bounded [Platje and Seidel, 1993; Thiry, 2004; Unger et al., 2012]. Public organizations logically seek opportunities to distribute the available resources optimally across all (MR&R) projects to ensure overall performance. A way to achieve this, is the so-called fit-for-purpose approach. This approach states that: *"The project best solves the problem for which it was initiated; given the other alternatives it was the best choice."* [Koops et al., 2017, p. 1314]. However, what if there are multiple conflicting objectives which are all likely to be fulfilled? All objectives are naturally desirable to be fulfilled, but tend to have an ambiguous and conflicting character [de Bruijn and Dicke, 2006; Bozeman and Beck Jørgensen, 2007; van der Wal, 2008; Reynaers and de Graaf, 2013] and may lead to conflicts as different involved actors deem certain objectives more important than others [de Graaf and Paanakker, 2015; de Graaf et al., 2016; Koops, 2017; Kuitert et al., 2019]. Therefore, decisions for project configurations are dependent on the present project characteristics like complexity, size and resources which need to be fitted to the project specific requirements [Weijde, 2008].

Edkins et al. [2013] state that the front-end development (read: FED) is the most significant stage for creating opportunities to create value in a project. However, the necessary information to properly configure MR&R projects is limited during the FED of projects [Samset, 2009]. This situation creates uncertainty as it becomes hard to attribute a definite probability to the outcomes of made decisions [Stahl and Cimorelli, 2005]. Absence of information during the early FED stages hampers and postpones decision-making on the development of MR&R projects, which is followed by grand investments in the accumulation of (relevant) information to reduce or absorb uncertainty [Perminova et al., 2008]. The present level of uncertainty in these early project phases also leads to a difficulty to determine which information is relevant to reduce uncertainty and support decision-making [Samset, 2009]. All in all, decision-making regarding the configuration of MR&R projects given these challenges is a complicated process. Given the urgency of MR&R interventions at certain assets, this process may lead to difficult and even dangerous situations.

1.1 RESEARCH SET-UP

1.1.1 Problem statement

Once an asset is determined to be in need of a MR&R intervention, a public organization has to take action. As expressed in the introduction, the FED of MR&R projects is governed by high levels of uncertainty, numerous configuration options and interrelated decisions. Decision-making regarding the configuration of MR&R works on an asset is therefore complicated. While both scientific research and practical experience on this issue is lacking, the need to explore a method to tackle this emerging complex situation is clear.

To clarify the current problem, the dynamics during the FED of MR&R projects within public organizations can be visualized as a so-called "black box system". This system can be viewed by its inputs and outputs, without any knowledge about its internal workings, as visualized in figure 1.1. Aging assets enter the box and projects ready for further development are output of this process. The dynamics which go on during this process are unknown to a great extent, whereas their effect on the organization, other MR&R projects and their environment are significant [Samset, 2009]. Exploring the ongoing dynamics inside this black box is therefore of major importance. By getting insights in the current dynamics, it is intended to express what currently happens during the FED of MR&R projects and what could be done inside the box to appropriately turn the input into output.

Figure 1.1: Overview of the black box system visualizing the FED of MR&R projects

1.1.2 Research objective

The aim of this research is to explore the challenges regarding MR&R project configuration and show the decision-making opportunities public authorities have in dealing with this challenge. Underlying reason of this aim results from the presence of asset transcending configuration options which affect the possibilities to achieve improved outcomes compared to an one-asset-one-project approach. As the amount of MR&R projects will logically increase in the future, public authorities are now seeking solutions to find a way to either maintain, renew or replace the increasing amount of soon-to-be outdated assets in a convenient matter [Nicolai et al., 2016]. Convenient in this context, refers to the extent public authorities choose an alternative which complies to the present requirements given the available resources, i.e. fit-for-purpose [Koops et al., 2017].

To provide grip on the complicated FED of MR&R challenges, present complexities are investigated to turn the present "black box system" into a overview of the ongoing processes and related decision-making. Since current knowledge regarding the FED of MR&R projects is relatively scarce, the objective of this research is to investigate the FED process and visualize the decision-making opportunities for MR&R projects by developing a decision-making framework which is generalizable for MR&R projects in the Dutch transportation infrastructure sector (Dutch: Grond-, Weg- en Waterbouw). Rationale for this objective raises from the current challenges public authorities are facing in finding appropriate ways to transform their aging assets into fit-for-purpose projects which are ready for further execution after the FED.

1.1.3 Deliverables

To turn the research objective into tangible output of this research, a set of deliverables is formulated. These deliverables figure as the primary elements of this research. The deliverables of this research are:

- Provide an overview of the main complexities of MR&R challenges which influence the FED process
- Develop a framework to support public organization in organizing their FED process to deal with their emerging amount of aging assets in a fit-for-purpose manner

1.1.4 Research question

Based on the research objective, the following main question has been formulated and will be answered at the end of this research:

"How can decision-making on the MR&R interventions of the emerging set of soon-to-be outdated assets be supported to configure assets in a fit-for-purpose manner?"

1.1.5 Sub-objectives and sub-questions

Given the comprehensive research objective and corresponding main research question, an answer is composed by splitting the main question up in multiple sub-objectives and related sub-questions. Since the FED of MR&R projects lack a substantive scientific background, the first objective is related to the creation of a theoretical background which merges the relevant aspects in an overview. Based on this theoretical background, empirical data is gathered to stuff the developed context of the FED with empirical knowledge. By doing so, actual challenges which occur during the FED are aimed to be revealed. These findings function as a starting point to develop a decision-making framework, which aims to structure and visualize the present dilemmas during the FED of MR&R projects. While the aim is to come up with applicable and rather generalizable recommendations to configure MR&R projects in a fit-for-purpose manner, the decision-making framework needs to be tested and validated. Therefore, testing the framework in an existing MR&R case and critically reviewing it by experts in the field is aimed to improve the desired quality of the framework and related recommendations for future MR&R projects. Below, an explanation of the individual sub-objectives and related sub-questions of this research is provided.

Sub-objective 1 - Create a theoretical background on the FED of MR&R projects

Sub-question 1 *- "What aspects cause the complexities related to the decision-making on project configuration during the FED of MR&R projects according to literature?"*

Before the decision-making framework can be designed, the research needs to build a theoretical background which describes the ongoing dynamics during the FED of MR&R projects. The theoretical background will primarily focus on the work related to MR&R projects, the role of the FED in such projects and the elements which influence the decision-making of MR&R projects during the FED. The aim of this sub-objective is to develop a conceptual framework which consists of the core elements related to the decision-making during the FED of MR&R projects.

Sub-objective 2 - Gather empirical insights in the main challenges related to the configuration of projects during the FED of MR&R projects

Sub-question 2 *- "What are the main challenges related to the decision-making regarding configuration of MR&R projects in practice?"*

Main aim of this sub-objective is to gather empirical data on the challenges which prevail during the FED, based on factors which were determined in the theoretical background of the previous sub-question. By analyzing what affects public authorities' idea of fit-for-purpose, an insight of the present complexities are to be found. This is be done by conducting exploratory interviews, analyzing project guidelines and a multiple case analysis which are focused on the FED process and the content which influences the decision-making.

Sub-objective 3 - Develop a decision-making framework for MR&R projects

Sub-question 3 *- "How could the FED process be designed to deal with MR&R projects in a fit-for-purpose manner?"*

Since the need for a bright overview of the decision-making possibilities to shape the FED process is evident, a framework is developed. The framework is composed of the present dilemmas which are retrieved from the earlier identified complexities in sub-questions 1 and 2. This decision-making framework presents an overview of the decisions which lead to a design of the FED process of a MR&R challenge. The main purpose of this decision-making framework is to break with the current inefficiencies and challenges of the observed cases in a structured manner. By visualizing the present opportunities to adjust the FED procedure, public organizations have a structured overview of the options to adjust their FED procedure to their desired outcomes.

Sub-objective 4 - Test the validity of the framework based on empirical knowledge

Sub-question 4 *- "What are the effects of empirical reviews on the performance of the framework?"*

Yet, as this framework is part of an exploratory research, it has to be validated. In order to validate the decision-making framework, an imitation experiment and an expert review session are held. By performing an imitation experiment analysis on the ongoing 'Vervanging en Renovatie Opgave' of Rijkswaterstaat, the decision-making framework is tested. Based on the characteristics of the existing MR&R case, the framework is challenged in an existing situation. Results of this test are intended to reveal potential inconsistencies and defects of the decision-making framework. Next to the experiment, an expert meeting is organized to validate the decision-making framework by a group of practitioners. By using the experience of multiple experts, inconsistencies between the framework and the actual practice are sought. Using these insights should leads to an updated framework which is tested in practice and validated by experts.

1.1.6 Scope

Four points of attention are identified related to the scope of this research. Firstly, this thesis will focus on MR&R projects within the transportation infrastructure sector. MR&R projects occur in all sectors, differing from IT to aerospace engineering. By conducting an analysis which focuses on MR&R projects in a multitude of sectors, results would probably be too generic to provide insights in the present issues of MR&R projects within the transportation infrastructure sector. On the contrary, focusing on one single MR&R challenge would be to specific, as complexities may differ among several cases. Strength of this thesis is in the combination of sector specific research combined with multiple insights from different public authorities. By comparing the challenges during the FED process of multiple public authorities which encounter (broadly) the same issues given the aging of relatively similar kinds of assets, the added value of this delimitation is intended to be the largest.

Secondly, MR&R projects are complex multi-actor systems with close relations between client, contractor and their environment (nearby residents, infrastructure users etc.). The decision was made to conduct this research from the perspective of the public organization, which plays the role of client in the earlier mentioned trinity. The rationale behind this decision is related to role and mandate they posses in transportation infrastructure MR&R projects. Given their responsibility to safeguard (public) values and having at the same time the duty to commission present MR&R projects, their role is leading in the determination on how to deal with the emerging problem of soon-to-be outdated assets. While the focus of this research is to determine how the assets can be transformed into projects in a fit-for-purpose manner, it is decided to take the perspective of a public organization. Nevertheless, this does not insist that the interests of contractors and the environment are not taken into account.

Thirdly, the reason for the delimitation of the thesis into the FED of MR&R projects is as follows: As the aim of this research is to identify opportunities for successful configuration of MR&R projects and the room for these opportunities is considered to be largest during the early phases of projects, the decision was made to to focus primary on the FED. Incorporation of the subsequent project phases would improve the overview of opportunities to guide a MR&R project towards a successful outcome. However, as this research is limited to a pre-determined time frame, certain trade-offs have to be made. The decision to incorporate all steps of the project life cycle would immediately reduce the ability to thoroughly dig into the dynamics of the FED.

Lastly, the complexities related to the configuration of MR&R projects during the FED phase are investigated from an institutional level, instead of an policy-and-program or actor level [Kuitert and Volker, 2016]. The decision to investigate the challenges from an institutional level rises from the idea that MR&R challenges touch upon all existing divisions and related operations of an organization. Analyzing MR&R projects from an strategic level should create an overview of ways to deal with the challenges in a comprehensive manner. Investigating the related challenges from lower levels in an organization is assumed to miss the 'bigger picture' and create sub-optimal solutions for public organization to deal with their MR&R challenges.

1.2 RELEVANCE OF THE STUDY

The relevance of this study will be discussed on a social, scientific and project level. By being connected to different fields of interest, this research is intended to have impact on multiple stages.

1.2.1 Social relevance

As explained in subsection 1.1.6, realization of infrastructure projects by public authorities are subject to public values. Decision-making on the configuration of MR&R projects during the FED influences the fulfillment of a broad set of (public) values. Given the responsibility of public bodies, substantiated trade-offs need to be deliberated. Within MR&R projects, opportunities arise to upgrade or replace outdated assets and systems with present day techniques and materials. For example, the use of concrete alone is responsible for 5 to 7 % of the yearly emission of greenhouse gasses worldwide [Kreijveld, 2018]. Innovations, stimulating the reuse of old materials and the development of cleaner alternatives may come with a higher price but could be necessary to decrease the ecological footprint of construction projects. Thereby, there is a considerable financial relevance related to this research as the costs of MR&R projects are direct public expenditures. The Dutch government, divided into several public division, is responsible for the commissioning of most public works in the Netherlands. In 2019 alone 9.5 billion EUR was available for the Ministry of Infrastructure and Water Management to invest in the accessibility, livability and a pleasant living environment of the Netherlands. [Rijksoverheid, 2019]. With the increasing amount of aging assets, the amount of to be renewed or replaced infrastructure will increase as well. As this research investigates the opportunities to configure projects in a fit-for-purpose manner, improvement of financial performance may have significant impact on the effectiveness and efficiency of public authorities. Succinctly stated, by investigating the opportunities of public authorities to have impact on urgent matters like climate change and financial performance, this research is intended to have significant social relevance as it is directly related to important public values.

1.2.2 Scientific relevance

Taken from the scientific perspective, MR&R projects provide significant different challenges compared to so-called greenfield projects [Vanier et al., 2000; Chen and Bai, 2019]. Due to the interaction with their environment, the other existing assets and networks, either renewal and replacement will have unique risks and considerable consequences. On the other hand, having a cluster of soon to be outdated assets within portfolio of a public authority, also brings certain opportunities while configuring MR&R projects [Koppinen and Rosqvist, 2010]. Scientific research in the field of public infrastructure development has primarily focused on greenfield projects and to a lesser extent on renewal and replacement. Digging into the relatively new and underexposed challenges and opportunities to successfully carry out MR&R projects, should contribute to an improved insight in the opportunities which arise during the FED.

1.2.3 Project relevance

In line with the motivation for this study, the ongoing 'Vervanging en Renovatie Opgave' of Rijkswaterstaat and other MR&R projects present the challenges this research is trying to overcome in terms of improving the performance of MR&R projects by investigating the opportunities which arise during the FED. By analyzing and comparing the FED of multiple MR&R projects, it is key to find potential opportunities to improve the overview of the present challenges. Doing this, the intention is to increase to opportunities for fit-for-purpose project configuration. Through analyzing the FED of multiple public authorities independently in the light of this thesis, potential causes of misalignment between configuration opportunities and present challenges can be investigated in an unbiased manner which may lead to new insights. While the 'Vervanging en Renovatie Opgave' and other MR&R projects will pursue for a longer period of time, the results and recommendations of this research will potentially be of significant value to the (future performance) of the project.

1.3 RESEARCH STRATEGY AND METHOD

1.3.1 Research strategy

First of all, this study is exploratory in nature while little knowledge on the specific subject is present. The research moves at the interface of the research fields of: Maintenance, renewal and replacement challenges, project and program management and front-end development, where aspects like interrelatedness of decision-making and presence of uncertainty and urgency have already been highlighted in the introduction. Nonetheless, these research fields are jointly investigated and shape the scientific body of this research. Because of the exploratory character of this research and the combination of theoretical knowledge and empirical data, a combination of a theory-oriented and a practice-oriented research focus is used. The distinction between different orientations is reflected in the aim of the several sub-objectives, which will be answered according to the appropriate strategy. Because of the twofold of research approaches, a strategy for each orientation is set-up separately. The strategies are based on Verschuren et al. [2010], where three key-decisions are taken into account:

1. **Breadth vs. In-depth** - Gathering a broad perspective of a certain context or digging in detail into certain phenomena.
2. **Quantitative vs. Qualitative research** - Execution of the research and representation of the results of the research are either based on graphs, tables and numbers or rather in a descriptive and contemplative manner.
3. **Empirical vs. Desk research** - A distinction is made between the observation and search for relevant data in practice in contrast to gathering and investigating existing research material.

[Verschuren et al., 2010] list five important research strategies which can be followed. These are: a survey, an experiment, a case study, a grounded theory approach and a desk research. Except of the desk research, the remaining research strategies have an empirical-orientation. Within the different strategies, several variants exist. As already mentioned before, this research exists of both a theoretical-orientation and an empirical-orientation. Related decisions on the research strategies have been made for the separate research orientations, which are presented and elaborated in table 1.1.

1.3.2 Research method & data gathering

To execute the strategy as presented in the previous section, data has to be collected and analyzed. Explanation of the research method will therefore be provided in this section to ensure reproducibility. By explaining the separate research steps it is intended that the same research can be conducted by someone else. The research process will be further explained in the following paragraphs.

Chapter 2 - Theoretical background on the FED of MR&R projects

Based on the input of the introduction, problem statement and research questions, a theoretical background is developed by conducting a secondary literature review. The content of this literature review mainly consists scientific literature on the related topics of MR&R projects, FED and configuration opportunities. Altogether, this will form the theoretical basis for a conceptual framework of the FED of MR&R projects which can be used to analyze several MR&R projects. By performing a desk research before investigating several cases, the theoretical basis will function as a pair of glasses through which the empirical cases will be analyzed [Verschuren et al., 2010]. Main sources for the literature study are ASCELibrary, ScienceDirect, Springer, ResearchGate, Taylor and Francis and the TU Delft Repository.

Chapter 3 and 4 - Main objectives and challenges of MR&R projects

While having the the conceptual framework as a starting point, this chapter will be about finding the empirical data to gain in-depth insights in the present complexities of MR&R project configuration from a practice point of view. To get this data, a comparative case study is conducted investigating several different MR&R projects throughout the Netherlands. Data collection is conducted in two ways. First, project related documents like project plans, policy documents and evaluation reports will be

		THEORY-ORIENTED		PRACTICE-ORIENTED	
		Choice	**Elaboration**	**Choice**	**Elaboration**
D1	**In-depth vs. Breadth**	Breath	Put MR&R projects, FED and decision-making in its context	In-depth	Reveal the explicit causes of present complexities and validating several elements of the FED process in depth.
D2	**Quantitative vs. Qualitative**	Qualitative	Results will be analyzed and processed in a contemplative manner instead of graphs and figures	Qualitative	Results will be analyzed and processed in a contemplative manner instead of graphs and figures
D3	**Empirical vs. Unempirical**	Unemprical	Combining scientific knowledge on relevant research topics	Empirical	Gathering existing challenges and objectives in real-life MR&R projects
		+			+
	Research strategy	Desk research	The theoretical background is decided to be completely on existing literature and existing material, which corresponds with a desk study approach.	Case study & Experiment	In-depth, qualitative and empirical research are characteristics of a case study approach. These aspects match the set-up of the practical part of this research. Thereby, testing the effects of a decision-making framework on the FED of a MR&R project corresponds with the characteristics of an experimental approach.
	Variant	Secondary research strategy	Rearrangement of existing scientific literature and interpretation from a different perspective is what will form the theoretical base of this project. By gathering the scientific research on MR&R projects, FED and decision-making, this will function as the body of this research.	Comparative case study & Imitation experiment	Systematic differences are intended to be found by comparing several MR&R cases in a hierarchical order, based on the boundaries set in the theoretical background. As the consecutive aim is to explore the functioning in an existing situation, the developed decision-making framework will be tested in an existing MR&R case.

Table 1.1: Elaboration of the research strategy, based on Verschuren et al. [2010]

consulted. Thereafter, semi-structured interviews will be held with several involved persons, to gain an extensive overview of the decision-making process during the FED of multiple MR&R cases. The semi-structured interview will be guided by a structured overview of interview questions listing the several elements of the conceptual framework. However, it is chosen to conduct the interviews in a semi-structured manner, as the potential to discuss new insights and ideas is assumed to be valuable and worth to discuss in more detail, given the exploratory character of this research. Thereby, it could be that present scientific research on which the conceptual framework was based, missed certain aspects that practitioners determine to be important in MR&R projects. Including such elements will contribute to the quality of the to-be-developed decision-making framework.

Chapter 5 - Development of a decision-making framework

Based on the the empirical data and the theoretical background, dilemmas are composed. Merging these dilemmas in a decision-making framework, should create an overview of ways to deal with the emerging amount of aging assets public authorities are dealing with. By using the decision-making framework, the flow of assets is controlled in a fit-for-purpose manner and converted to a matching configuration option accordingly.

Chapter 6 - Testing and validating the framework

Despite the empirical and scientific background of the decision-making framework, it is tested and validated to improve the quality and reliability. This is done by a combination of two methods. First, an existing MR&R case of Rijkswaterstaat is taken for an imitation experiment. By imitating the exact characteristics of the case and applying the decision-making framework, it is intended to check whether the framework works. Using the framework in this case, should lead to insights about the way the frameworks works and whether it works. Analyzing the process and the outcomes of the framework application is is intended to check whether the framework works as expected: to configure the flow of soon-to-be-outdated assets in a fit-for-purpose manner. Besides, insights of experts in the field are relevant to check and validate the decision-making framework. Potential inconsistencies and defects are intended to be gathered from the expert opinions and processed in the final and updated decision-making framework.

A visual overview of the research process is presented in figure 1.2.

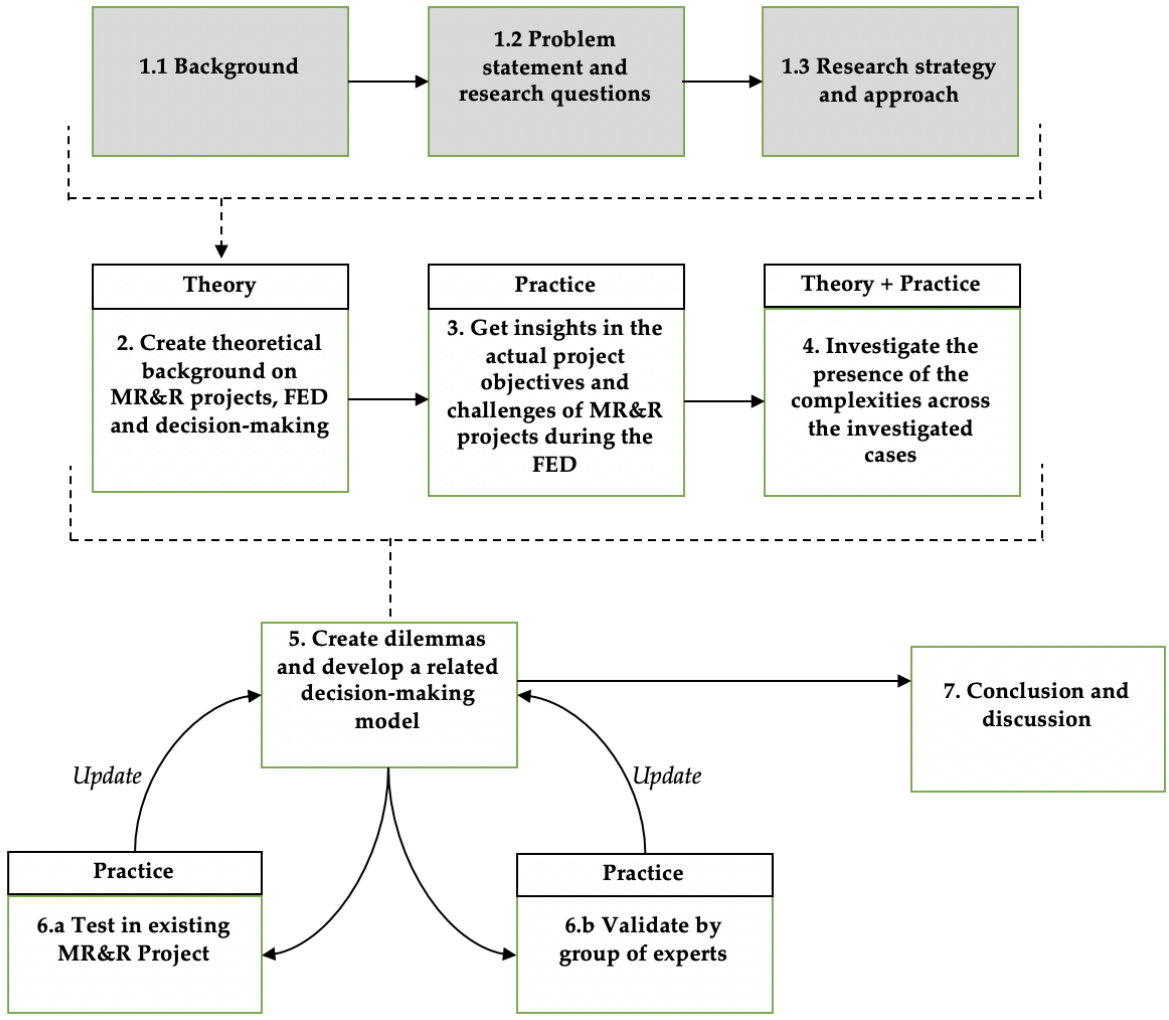


Figure 1.2: Overview of the research process

1.3.3 Validity

The secondary literature review on MR&R projects, FED and decision-making was designed to optimize validity. By consulting a variety of scientific project management journals and business sources that are generally accepted by the industry, a representative overview is acquired. Regarding the

comparative case analysis, a not-representative sample was considered: three public commissioning authorities were the unit of research. The cases are selected on several criteria. Obviously, the cases must be MR&R projects within the transportation infrastructure sector. A comparison among these cases will be useful as the same kind of assets with the same conditions are dealt with. This prevents that the comparison is made between apples and oranges. To make the decision-making framework generalizable for other public authorities facing MR&R challenges, it is useful to involve a variety of public authorities in the case comparison. Furthermore, within these organizations a limited sample was chosen (a relatively random selection of MR&R projects) because of time restrictions and the presence of contacts of contacts of the researcher.

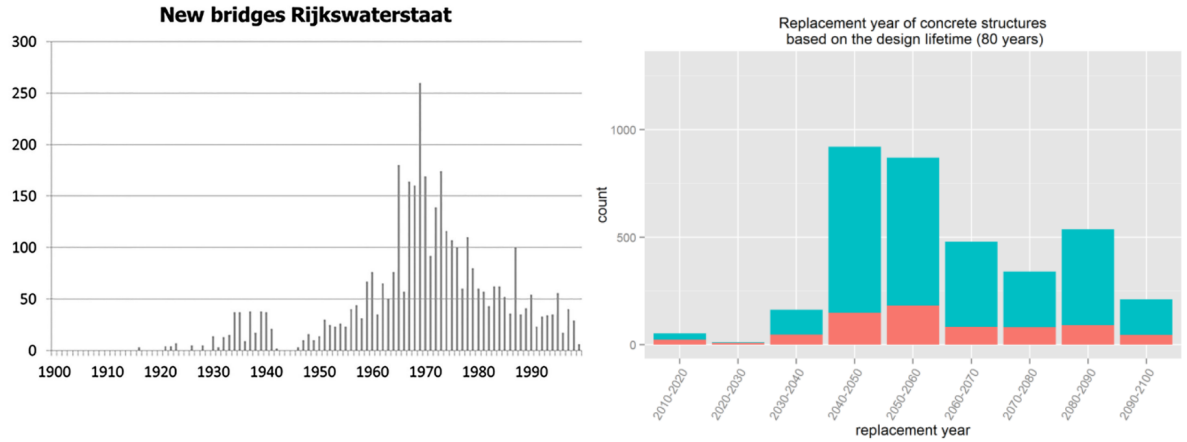
External validity is intended to be improved by conduction an expert review session. Performing a test of the decision-making framework on a single case was intended to improve the internal validity of the developed framework. However, testing it only to one case still limits the internal validity to a limited level. The research methodology that was developed and used in this research project can be easily extended to other owner organizations in the transportation infrastructure industry, as the decision-making framework uses relatively general variables. Regarding the exploratory interviews and the expert validation session, the objectivity of the participants could not be verified. Sometimes answers of the interviewees may not correspond with the present project documents, which could be the consequence of subjectivity. This decreases the validity of the research. All-in-all, it is hard to prove generalizability of the developed decision-making framework and the related recommendations for future MR&R projects. Carrying out more tests on other MR&R projects and conducting multiple expert validation sessions with persons from other public organizations would likely increase the internal and external validity.

2 THEORETICAL BACKGROUND ON THE FED OF MR&R PROJECTS

The first step in the development of the decision-making framework is dedicated to opening up the black box of figure 1.1. Main objective of this chapter is related to determining the complexities which influence the configuration of MR&R projects during the FED. By first digging into the opportunities to look beyond asset borders, the basics for configuration grounds are set. To get an improved on the challenges related to the configuration in a MR&R context, main characteristics of MR&R interventions and the distinction between the intervention options are explained. However, before these MR&R works can be executed, several preparatory steps take place. The FED plays a special role in these preparations and therefore demands further explanation. By conducting a secondary literature review on the importance and content of the FED, in combination with the discussion of two examples, a theoretical background on the decision-making process of MR&R projects is to be created. The decision-making process will thereafter be decomposed in both elements and process related aspects which influence the FED. These aspects will be individually discussed, to create a better understanding of the dynamics and interrelations from a theoretical point of view. Altogether, these interactions shape the theory-based conceptual framework, which summarizes the whole of dynamics related to the decision-making on MR&R project configuration during the FED.

2.1 INTRODUCTION

Impressive construction numbers to foster economic growth in the previous decades, has created an unstructured and significant challenge related to the nowadays state of the infrastructure assets. As presented in figure 2.1a, the construction of bridges by Rijkswaterstaat between 1900-2000 shows a significant increase after WWII. As a direct consequence,Nicolai et al. [2016] estimated that the so-called baby boom of civil structure construction will lead to a replacement demand [1] in the 21st century, as shown in figure 2.1b.



(a) Yearly delivery rates of new bridges by Rijkswaterstaat in the 20th century [Hertogh et al., 2018]

(b) Replacement year of concrete civil bridges (green) and overpasses (red) in the 21st century [Nicolai et al., 2016]

Figure 2.1: Overview of the construction and estimated replacement years of Rijkswaterstaat's civil structures

Observation of 2.1 presents a visualization of the major challenge Rijkswaterstaat and other public organizations are facing in the coming decades. These images just show the construction and replacement

1 Given a design lifetime of 80 years

rates of Rijkswaterstaat's concrete bridges. An additional factor which created the size of the upcoming MR&R challenge, is the significant increase of user rates and environmental effects [Hassanain and Loov, 2003]. With an asset collection consisting of tunnels, locks, sheet piles, flood defence system and many more assets, these images just show a fraction of the total conservation challenge in the coming decades.

2.2 OPPORTUNITIES TO LOOK BEYOND ASSET BORDERS

Options to deal with MR&R challenges can be roughly reduced to the decision to carry out the MR&R activities in an individual and independent manner or in a shared environment together with other projects. In scientific literature, this distinction is often referred to as an project-based or program-based approach, respectively [Van Der Merwe, 1997; Atkinson, 1999; Schwindt and Zimmermann, 2015]. The former is characterized by a temporary and relatively short-term phenomenon which is carried out in isolation and managed singularly [Evaristo and Van Fenema, 1999; Sydow et al., 2004]. The focus is mainly on effective management of activities to deliver the project within the approved time, budget and quality [Burke, 1999; Nicholas and Steyn, 2012]. The latter is an integrated approach that can streamline the effective delivery of projects with both a focus on strategy and overall performance [Pellegrinelli, 1997; Rijke et al., 2014]. By managing a group of projects, there is an intense cross-discipline and cross-project integration in which the actions of one project affects, supports and reinforces the other projects in the program [Shehu and Akintoye, 2009].

Choosing for a project-based approach has certain advantages. Known procedures can be followed and by accommodating these MR&R projects in existing divisions, standardization benefits can be exploited [Sydow et al., 2004]. On the contrary, the decision to work in a program-based manner, creates a broad set of opportunities regarding the development of the projects [Heising, 2012]. Programs are known for their opportunity to create benefits over and above the ability of a single project, due to integral risk management, prioritisation, more efficient use of resources and improved alignment with other projects [Pellegrinelli, 1997; Gray, 1997]. Contractors can be involved in the early project phases in a non-committal manner to align potential goals and intentions [Liu et al., 2019]. For example, by having a certain body of similar assets, opportunities for economies of scale in procurement may pop up [Boes and Dorée, 2008; Nucciarelli et al., 2010]. Thereby, van Buuren et al. [2010] describes another advantage as the created division can act as a 'shared service center' where the management of knowledge across multiple projects can be integrated in terms of financial, legal, administrative and technical services. Creation of a program environment also creates the opportunity to deal with changes, through learning over projects [Thiry, 2002]. Learning is seen as a critical elements to mobilize expertise which leads to a better understanding of the present processes and possibilities within an (MR&R) environment [Liu et al., 2019].

However, program management is not eminently the holy grail to develop integrated solutions for multi project challenges. Due to close relation between the program and underlying projects, managing these interfaces rises various difficulties [van Buuren et al., 2010]. One of these difficulties is related to the so-called 'span of control'. The span of control increases as the number of components and actors increases, which leads to a larger variety and greater interdependence [Leijten, 2017]. However, difficulties occur when the complexity of a project exceeds the span of control of a project management organisation [Leijten, 2017]. As a result of impeded manageability, the program management focus may shift from coordination to control. Higher degrees of control in the program on the projects may lead to excessive levels of bureaucracy, which is counterproductive for the program as a whole [Westerveld and Hertogh, 2010]. Additionally, if the level of program management gets to detailed, strategic objectives may be faded which can lead to conflicts between project and program managers [Lycett et al., 2004]. Together, these aspects of control and bureaucracy conflict with the necessary level of flexibility programs should have, to adapt to the dynamics within the context of the related individual projects [Pellegrinelli, 2002; Sanderson, 2012]. Lastly, inter-project competition and failure to successfully set up an organizational learning environment tends to complicate the cooperation between projects [Platje and Seidel, 1993; Lycett et al., 2004; Shehu and Akintoye, 2009].

While the trend within public organizations is about to shift from realizing mostly greenfield projects towards the upkeep of the current network, options to look beyond asset borders are certainly there. Therefore, chances to employ these opportunities in a MR&R environment will to be explored in the following sections.

2.3 MR&R OPERATIONS

When it comes to decision-making on an asset level there is only a relatively limited set of options to choose from [Hertogh et al., 2018]:

- Maintenance - Measures through Service Level Agreements (SLA's).
- Renewal - 1:1 Renewal or upgrading functionalities to future demands
- Replacement - 1:1 Replacement or upgrading functionalities to future demands

As shown in figure 2.2, maintenance has minor effects on the state of an asset, whereas renewal (= rehabilitation) is applied to provide a significant boost to the asset condition. Logically, renewal is associated with larger expenses and only happens given a certain critically regarding the state of an asset. As the word itself already implies, replacement (= reconstruction) is the substitution of an existing (element of an) asset by a new one [Peshkin, 2011].

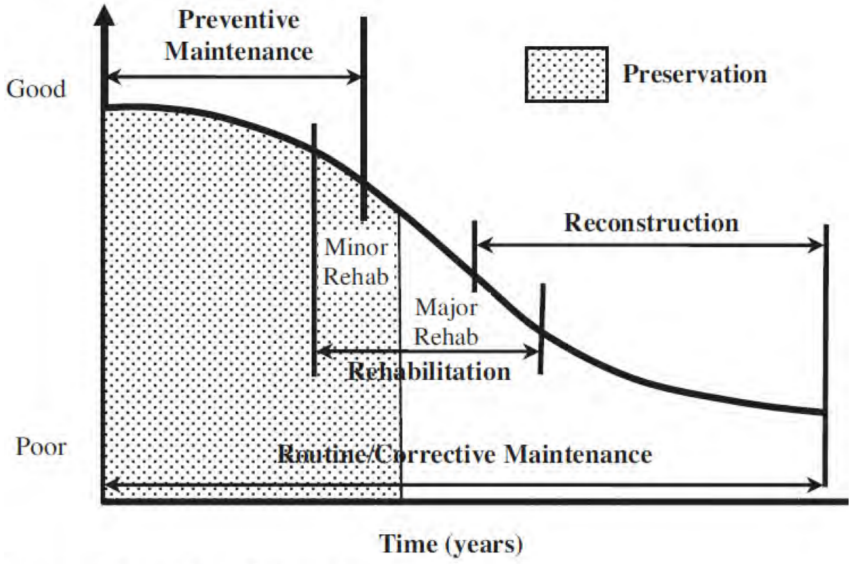


Figure 2.2: Overview of the different intervention measures [Peshkin, 2011]

The decision to choose for a certain intervention measure is based on numerous trade-offs, which will be discussed later on in this chapter. First, an explanation of the different intervention alternatives is provided in the following subsections to gain improved understanding about the differences between the intervention measures.

2.3.1 Maintenance

After an asset is built and ready for operation, the focus moves from building to maintaining an asset. In general, maintenance can be defined as the set of activities which restore the functional performance of an asset to the required performance level [Dekker and van Noortwijk, 2007]. Potential maintenance activities are inspections, reparations, replacements and life span extending measures. Carrying out life span extending maintenance is done to counteract the aging process and extend the life span, as shown in figure 2.3.

However, maintenance is not a catch-all term. In general, maintenance can be divided in preventive maintenance (before failure) and corrective maintenance (after failure). Failure can occur in two

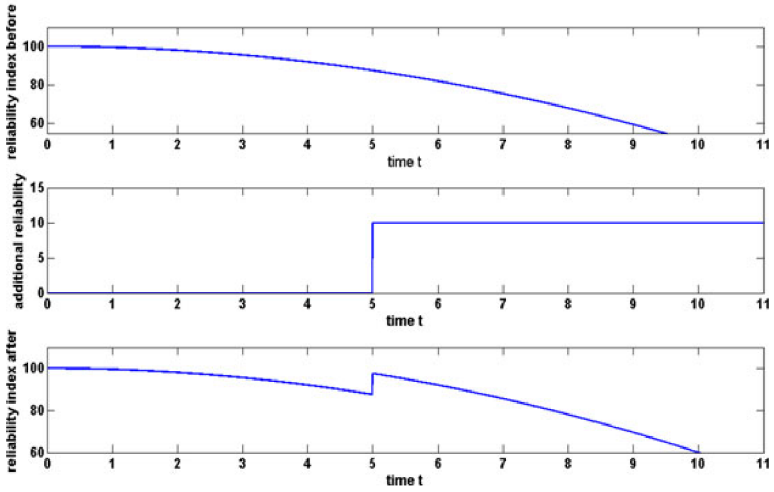


Figure 2.3: Reliability index before (upper) and after (lower) maintenance, including the additional reliability profile due to maintenance (middle) [Ng et al., 2009]

ways, either normative failure or physical failure, respectively caused by exceeding stated failure and safety norms or caused by really succumbing or collapsing of an (element of the) asset [Brown and Humphrey, 2005]. Preventive maintenance is carried out to reduce the deterioration process without renewing the elements in the existing systems, often merged in so-called Service Level Agreements (SLA's) [Frangopol and Liu, 2007]. Preventive maintenance can be further divided in time, use, load and state dependent preventive maintenance, as shown in figure 2.4. Time, use and load dependent maintenance are all carried out after a certain amount of time, just like refilling the oil of a car after every 15.000 kilometers. State dependent preventive maintenance is based on the inspection of assets and the observed state, which can be better, equal or worse than the stated safety norms. Accordingly, nothing, preventive maintenance or corrective maintenance has to take place [Zimmerman and Peshkin, 2003].

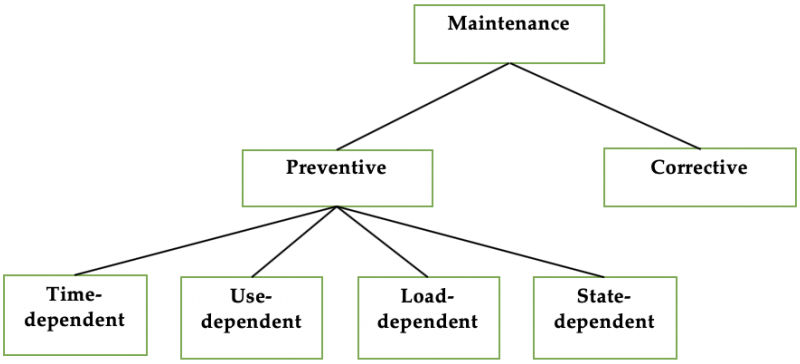


Figure 2.4: Division of maintenance types (based on [Dekker and van Noortwijk, 2007]

Maintenance strategies are mostly related to available annual budgets [Schraven et al., 2011]. A strategy focusing on preventive maintenance is facing often facing balanced expenses over a longer time frame. While these annual preventive activities are often combined with inspections, relatively up-to-date information regarding the status of assets is kept. Planning of related larger-scale maintenance, renewal or replacement interventions are to be made on (relatively) accurate data, as deterioration information is gathered over a longer time-span [Mild et al., 2015]. However, executing preventive maintenance on an annual basis leads to higher expenses on a short-term, compared to doing nothing until something goes wrong and having a strategy focusing on corrective maintenance [Lingegård and Lindahl, 2015]. In fact, practice often shows a hybrid combination of both strategies, balancing preventive and correc-

tive maintenance [IAM, 2015].

Next to the different kind of maintenance strategies, it also exists in numerous shapes en sizes. (Daily) maintenance often includes short-term maintenance (<1 year) and can be both preventive and corrective. Main aim of this kind of maintenance is to maintain the life span of an asset and eliminate unsafe situations which occur unexpectedly. As the maintenance activities shift towards a longer time span (1-5 years) and still include preventive and corrective maintenance works, it is often referred to as renewal, instead of maintenance [Schraven et al., 2011; van Riel et al., 2017]. Another difference between maintenance and renewal is the use of the existing and new systems to improve the current state of an asset, respectively.

2.3.2 Renewal

In line with the sustainability trend of the recent decades, increased attention has been rewarded to the renewal of civil structures. Renewal mainly includes the repair and upgrading of sub-systems and select functional improvement to structures [Karydas and Gifun, 2006]. At one end of the renewal scale we find preservation or conservation of the original asset, whereas the other end of the scale we find reconstruction of an entire asset [Thuvander et al., 2012]. Scientific literature often uses the terms alteration, adaption, restoration, retrofitting, rehabilitation, upgrading or renovation as synonyms for renewal. The reason for this diverse terminology is due to the varied type of assets, the large range of actions and variety of reasons for making an intervention [Thuvander et al., 2012]. For the sake of clarity, all of the mentioned terms will be described converted to renewal in this research, which is defined as the middle range of the earlier mentioned renewal scale.

The comprehensive reason for renewal works is to upgrade asset functions at today's rapidly advancing standards [Casciati and Lagorio, 1996]. Examples of renewal works at bridges for example, are energy system upgrades, replacement of expansion joints and road surfaces and preservation of the surface in order to protect it from corrosion and wear [Zietlow, 2005]. By conducting intensive renewal works, the asset is intended to extend the service life for a couple decades [Frangopol and Liu, 2007]. Needless to say, this could also be achieved by replacing an asset with a new asset. However, the trade-off between either renewal or replacement rises a lot of questions. One boundary condition is related to the ability to improve the state of the asset in a cost-effective way [Kabir et al., 2014]. This will be further explained in the subsection 2.5.1.

Figure 2.5: Road surface replacement during the renovation of the A50 Ewijk Valbrug in 2013 *(Credits: Thea van den Heuvel - Rijkswaterstaat Image Bank)*

Compared to the project life cycle of new construction projects, renewal processes has relatively similar phases [Nielsen et al., 2016]. However, more emphasis is laid on the preparatory investigation phase in terms of time and resources, to appropriately prepare a sound renewal project [Karydas and Gifun, 2006]. Reason for this difference lays in the consideration that renewal project are highly complex, as it has to deal with complex structural systems with all related uncertainties of the mechanical behaviour of materials [Casciati and Lagorio, 1996].

2.3.3 Replacement

When an asset does not comply to the present laws and regulations on safety, (partly) replacement by a new (elements of the) asset becomes an option. Decisions to chose for replacement, instead of renewal can be numerous. Given the graph in figure 2.2, renewal is only possible in a certain bandwidth of the state of an asset. If the situation emerges when the condition of an asset is so poor, renewal may not even be technically and economically feasible [Preuß and Schöne, 2016]. Functionalities of an asset can sometimes be insufficient to present requirements. While the construction often took place decades ago, present-day usage of the asset may be different to what is was originally designed for [Hertogh et al., 2018]. Another argument in favour of replacement may be related to the environmental impact of an asset. If replacement of an (elements of the) asset leads to an improvement of the environmental impact than the present performance, replacement may be preferable to the current situation [Hermans, 1999]. Same goes for operational costs, if the replacement alternative shows (long-term) benefits compared to the current operation, replacement and its related costs do not form an obstacle to take action [Yu et al., 2018].

Replacement is a broad concept while assets often exists of multiple sub-systems. For example bridges, are often divided in the following elements (as visualized in figure 2.6 [Hassanain and Loov, 2003; Dicleli et al., 2005; Morcous, 2006; Abukhalil et al., 2019]:

1. Superstructure - General term for all elements which are anchored to a supporting structure. Part of the structure which supports crossing traffic and includes the deck, slab and girders.

2. Substructure - Element of the structure which supports the superstructure and transfers the structural load to the foundations. Parts of the substructure are piers and abutments.

3. Foundation - Components which transfers load from the substructure to the bearing strata beneath the asset. Dependent on the set-up of the soil, the depth of the foundation is determined.

4. Technical installations - Components of the bridge which ensure the operational functions like: Electric or mechanic technical installations, IT and operating tools.

Dependent on the state of (an element of) the sub-system, replacement may be necessary.

While replacement is accompanied by the installment of a new (sub-system of the) asset, the intended lifetime of the asset is same as for new assets. Dependent on the size of the replacement works, it is often accompanied by time or planning incentives, compared to renewal projects. By simply taking out the existing (element of the) asset and putting the new asset in place, the total time an existing asset can't be used (Dutch: buitendienststelling) is on average shorter compared to renewal works [Yang and Frangopol, 2018]. On the other side, the difference in costs between renewal and replacement works is significant as well [Schraven et al., 2011]. Replacing an asset that could be renewed, is therefore not common as this is seen as capital destruction [Provincie Flevoland, 2019; Noord-Holland, 2019].

The related trade-off to determine the appropriate MR&R intervention method is overall complex. Actual MR&R works are not stand-alone activities which have direct and indirect effect on the organization, the project and all related elements. As discussed in the previous section, execution of maintenance, renewal or replacement works goes along with thorough preparations and trade-offs. Therefore, the next section will further elaborate on the different phases of a project and the relation of these phases with each other. After that, section 2.5.1 will shed light on the related dilemma's to determine .

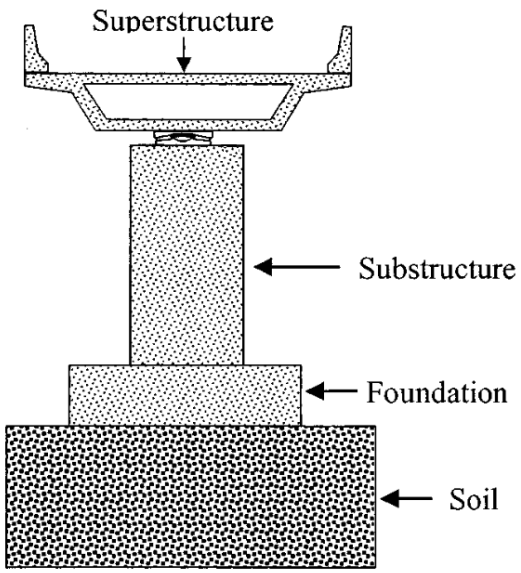


Figure 2.6: Components of a bridge [Dicleli et al., 2005]

2.4 PHASES OF A MR&R PROJECT

Projects are executed to develop a system by creating a new one or to improve existing ones [Nicholas and Steyn, 2012]. MR&R projects are no different. Development of this system is characterized by the so-called project life cycle as shown in figure 2.7.

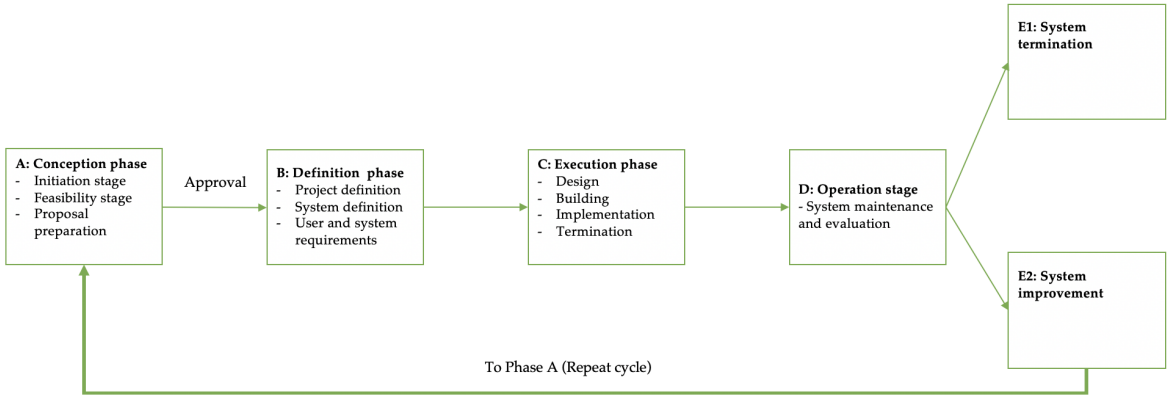


Figure 2.7: Overview of the project life cycle [Nicholas and Steyn, 2012]

Every phase in the cycle embodies a different objective and has related activities. Consideration of the actual problem the project has to solve and determining what intervention method could suffice to contribute to that, logically takes place in the first phase of the project. The so-called conception phase end with a proposal which is to be approved, before continuing to the more detailed preparatory phase: the definition phase. Here, the selected project is further defined and elaborated in more detail. By setting the boundaries of the system and defining user and system requirements, the projects is being prepared for the execution phase. Here the requirements are transformed into a detailed design which will be actually built. After the construction is finished, the operational phase takes over which

is accompanied by maintenance activities.

After a certain amount of time the system / project is evaluated, where determination whether termination or improvement is preferred. In the case of improvement, the cycle starts all over again. This is actually also the case in MR&R projects. After some time, developed assets are getting into a state which requires an evaluation. As termination of an existing asset in the present transportation infrastructure network is unlikely to take place given its contribution to the present network, reconsideration of the use of an asset takes place. Replacing an existing outdated asset by an alternative solution for the mobility issues is however thinkable. This would still lead to the termination and decommissioning of an asset, but is replaced by an alternative [Schraven et al., 2011; Bosch-Rekveldt et al., 2015]. This makes a difference to immediate termination, as new alternatives are considered before the decision to terminate the system.

2.4.1 Importance of the front-end development

Traditionally, large transportation infrastructure projects are characterized as complex, showing high levels of uncertainties and often fail to meet project objectives within the their initial budget and time boundaries. Research by Flyvbjerg [2007] showed that 90% of the observed large-scale bridges and tunnels, road and rail projects had cost overruns averaging between 20% and 44%. One of the reasons for these overruns can be related to the underestimation and negligence of project challenges in the preparatory phases of a project, which can have disastrous consequences as the project develops [Bruzelius et al., 2002]. As the MR&R challenge will continue for the coming decades among all public authorities, it is key to investigate all options to deal with an emerging set of aging assets. Regardless of the naming and framing of the preparatory phases of a project, a sound FED is avowed to be critical for ultimate project success [Batavia, 2001; Bakker, 2008; Smith and Winter, 2010].

Despite the different perspectives on project success, Koppinen and Rosqvist [2010] developed four major performance requirements MR&R projects of a public organization at least should comprise:

1. Alignment of strategy and operations with stakeholder values and objectives
2. Balancing of reliability, service-level, safety, and financial considerations
3. Ensuring optimal packaging and timing of works, and adequate competition
4. Promoting market development

To every of the stated general success dimensions, several measurable criteria can be derived. In order to comply to these success criteria, numerous factors should be encountered which influence the level of fulfilment. Fulfillment of the determined criteria will ultimately define the success of a project. Distinction of these mentioned success factors can be made into the project's tactical and strategic performance. [Samset, 2009, p. 2] explains the difference as follows: *Success in tactical terms typically would be to meet short-term performance targets, such as producing agreed outputs within budget and on time. These are essentially project management issues. Strategic performance, however, includes the broader and longer-term considerations as to whether the project would have sustainable impact and remain relevant and effective over its lifespan. This is essentially a question of getting the business case right, by choosing the most viable project concept."* Aiming for a successful project should therefore encounter both tactical as strategic performance of the project.

Given the complexity and uncertainty which develops throughout the different stages of a project, Burke [1999]; Samset [2009] state that the opportunity to create value for a project are the highest in the early phases. Besides, implementing changes in later phases of a project will lead to significantly higher costs, compared to the costs of similar changes in the early phases. This phenomenon, set out against the different project phases is visualized in figure 2.8. Research by Demirel et al. [2017]; Liu et al. [2019] acknowledge the findings of Burke and Samset in Dutch infrastructure projects as well, and recommend early-on identifications of potential challenges and opportunities along the early phases of a project.

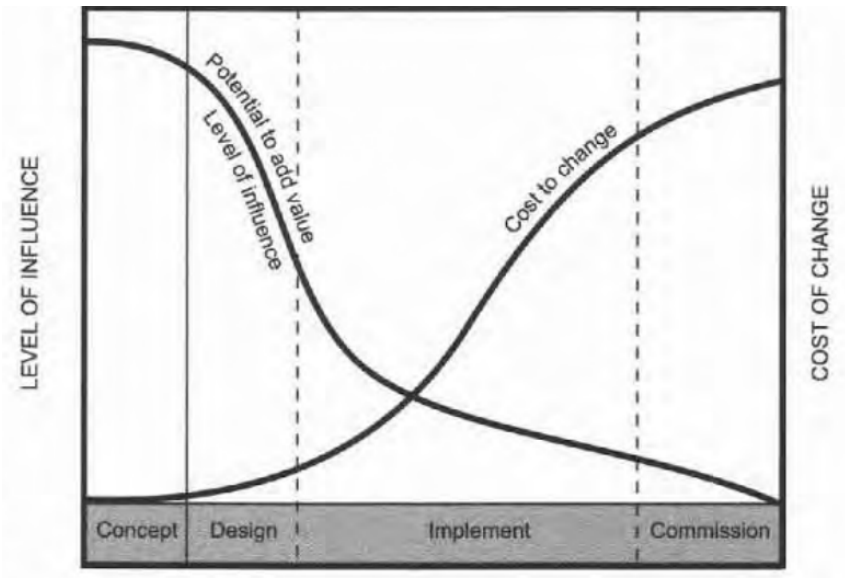


Figure 2.8: The potential to add value to a project over the project life cycle [Burke, 1999].

During front-end phases of large infrastructure projects, involved actors seem to have a tendency to look for potential factors which could decrease the chance of risks or consequences related to the fulfilment of pre-defined criteria [Volden, 2018]. Putting the prevention and mitigation of these threats on the agenda is a matter of course. However, finding a successful way to deal with such complexities in MR&R projects is less straightforward. Key issue in projects at their early stages is to pay sufficient attention on the underlying problem which justifies and exposes the needs of the project. Thereby, detailed information regarding alternative solutions appears to be less relevant. This causes a major dilemma, as projects tend to originate as one specific solution to a problem, instead of conducting a comprehensive problem analysis and considering alternative solutions [Samset, 2009]. By having a tunnel vision on dealing with these risks and omitting external factors may lead to public dissatisfaction and opposition later on in a project [Bruzelius et al., 2002; Van Wee and Rietveld, 2013]. Westerveld and Hertogh [2010, p. 241] state that premature convergence, where: *"(...) a solution is chosen early in the process, thereby 'killing off' the many other options present at that point in time."* is undesirable.

On the contrary, instead of looking at aspects that may cause failure, one can also investigate opportunities to contribute to the success during the front-end phases. According to Heising [2012, p. 582]: *At the front-end of projects, opportunities are discovered, ideas are created, and the foundation for later project, portfolio, and, eventually, corporate success is laid.* By extending the perspective from: What risks for project failure are available? to: What opportunities for project success are present?, an extensive interpretation of project success can be developed. In line with this ideology is the concept of opportunity framing, developed by Bakker et al. [2016]. This approach is focused on understanding and defining opportunities that add (societal) value to infrastructure projects. By looking beyond the physical boundaries of a project, the solution space for decision making on projects can be enlarged and prevents "killing off" present options in the preparatory phases of a project [Westerveld and Hertogh, 2010]. Early on reduction of the solution space is undesirable, as the project will become path-dependent [2] and opportunities for improvement are unlikely to be developed [Van Wee and Rietveld, 2013].

2.4.2 Content of the FED

Views on FED in scientific literature differ among various researchers. Terms like: front-end loading, value improving process, project definition phase are used in close related to FED [Weijde, 2008]. To create clarity on the FED is, the process can be separated in three sub-phases:

2 Path dependent refers to the dependency on previous outcomes rather than current conditions

- **FED 1 - Assess:** This phase is related to answering the question of: What is the actual case? Setting the project objectives and developing a business case together with the present constraints are part of this phase.
- **FED 2 - Select:** This phase aims to identify the best way to achieve the project objectives. Alternatives are considered in the light of the determined criteria during the previous phase. At the end of this phase, a preferred alternative is chosen and approved for further elaboration.
- **FED 3 - Define:** This phase is devoted to further development of the preferred alternative. By freezing the scope, more detailed development of the project takes place.

To put this in perspective, figure 2.9 visualizes the different FED phases in the project life cycle overview of [Nicholas and Steyn, 2012]. The FED can be defined as the period between the moment when an opportunity is first considered and when an idea is ready for further development [Kim and Wilemon, 2002]. Upon approval to pursue the project, the project life-cycle stages of design, construction, hand over and operation will commence [Edkins et al., 2013].

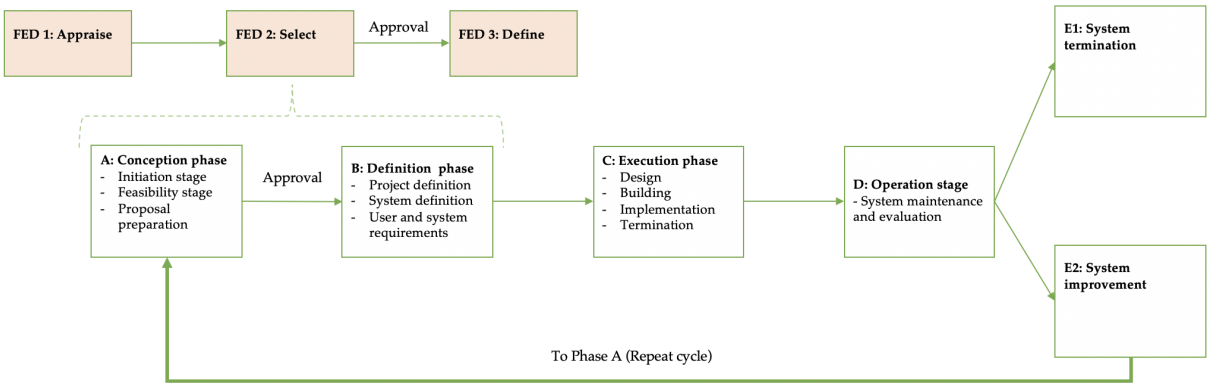


Figure 2.9: Overview of FED inside the the project life cycle, adapted from [Nicholas and Steyn, 2012]

Research by Cooper [1990] introduced the use of stage-gate systems to evaluate and filter the developments during the FED and consecutive project phases. The stage-gate system divides the PLC in different stages (i.e. phases) and places a 'gate' or 'checkpoint' between these stages to assess the quality of the projects which reach the gate. Every gate is supplied with requirements, a set of exit criteria and an output. By checking whether the project still meets the requirements, decisions to pursue, stop or revise a project can be made based on the intended requirements of a project [O'Connor, 1994].

As MR&R projects are different to greenfield projects because of working with existing assets, the use of FED is also slightly different. Normally, FED is carried out in order to determine and select the most promising project to be carried out [Gibson et al., 2006]. However, during the FED of MR&R projects, the ability to not execute a project and do nothing is absent. The nature of the decision options exist of the kind of MR&R interventions and certain configuration possibilities among the 'MR&R-needy' assets [Šelih et al., 2008]. Freedom regarding the decision to not incorporate certain aspects in their project from a set of present alternatives is however possible. This refers back to the determination to either renew or replace an assets 1-on-1 or upgrading it to future demands [Hertogh et al., 2018]. Assessment whether the made decision meets the intended outcomes of a project in a fit-for-purpose manner can however be assessed by the earlier mentioned stage-gate system [Gassmann and Schweitzer, 2014]. Instead of selecting the most promising projects, requirements to pass a gate can be developed which determine whether the chosen intervention meets the purpose and values of a project.

2.4.3 Two examples of MR&R configuration processes

Research by Šelih et al. [2008]; Nielsen et al. [2016] both resulted in an overview of the decision-making process during the preparatory phases of a MR&R project. Both processes are visualised in figure 2.10 and figure 2.11.

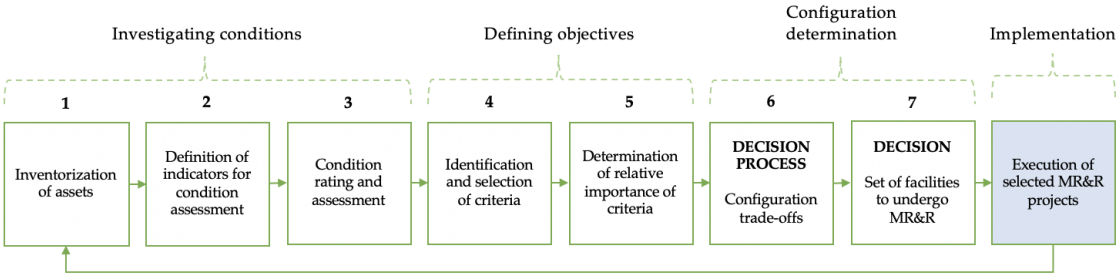


Figure 2.10: Overview of the FED process according to [Šelih et al., 2008]

The first three steps of Šelih et al. [2008] their process mainly focus on creating an overview of the state of the asset inventory. By formulating indicators and executing condition assessments, a scoring can be made for all indicators and aggregated for each asset. Main focus of these three steps is primary on the characteristics of the the aging assets. Next steps in the process are about determining the criteria on which the decisions regarding the MR&R project configuration are made. As these criteria and relative importance result from the requirements which should be incorporated during the decision-making, the focus expands from mainly technical into organizational, financial, social, legal and time related considerations [Westerveld and Hertogh, 2010]. Subsequently, the decision process takes the asset conditions and determined criteria as input for the trade-offs while determining a suitable MR&R project configuration. When the decisions are made and the projects are determined, implementation can take place.

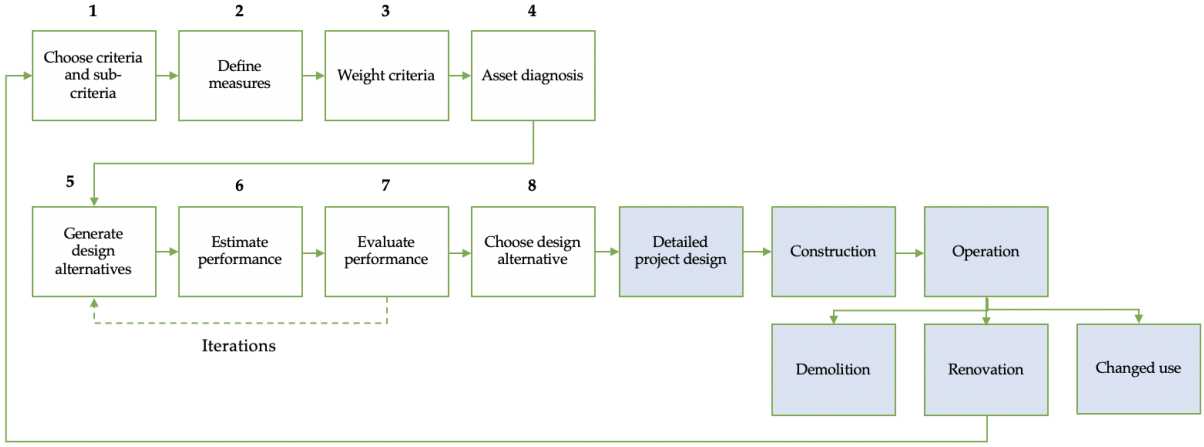


Figure 2.11: Overview of the FED process according to [Nielsen et al., 2016]

The process of Nielsen et al. [2016] starts with setting the goals, objectives and related criteria. These criteria are translated into measurable criteria. Before the asset diagnosis takes place, weights to the criteria are defined to determine their relative importance. As the weights may differ, this rank-order

weighting method has significant impact on the outcome of the decision-making process. The asset diagnosis takes place to consider the MR&R need of an asset. A balance should be found between the amount of information needed and the time available for collecting the data [Nielsen et al., 2016]. Based on the asset diagnoses and present criteria, several MR&R alternatives are identified. The performance of the alternatives in relation to the criteria is tested and thereafter evaluated. This evaluation takes place continuously and provides input for the development of new design alternatives. Finally, a decision is made regarding the preferred alternative. This alternative will be further developed in the subsequent project phases.

Main difference between both processes is the purpose of the process. The process of Šelih et al. [2008] is rather generic and focuses primary on the question whether to (not) start a MR&R project based on an asset's conditions. The process of Nielsen et al. [2016] also encounters the present alternatives and their effect on the performance of the asset. Steps 1-4 of figure 2.11 can be seen as the earlier discussed FED 1 assessment phase, steps 5-8 are more or less FED 2 where the preferred alternative is selected and FED 3 is visualized in the 9th step, which further develops the preferred alternative.

Another difference between the processes, is the order of the decision-making steps. The process of [Šelih et al., 2008] present the opportunity to not incorporate certain assets in the final decision to set-up a MR&R project. This originates from the purpose of the process, which is to optimally distribute the present resources of the asset manager among it's assets. In the process of Nielsen et al. [2016], the opportunity to do nothing is absent, as the focus is primary on the renewal of assets. Despite the difference between both processes, the disquisition of the process and related decision-making making trade-offs provide a useful insight of the ongoing dynamics during the FED of MR&R projects.

The outcome of both decision-making processes by Šelih et al. [2008]; Nielsen et al. [2016] is logically related to the formulated steps the process exists of. Next to the sequence of certain steps and decisions, the content of every step influences the outcome as well. The decision to formulate the criteria before the condition assessment, has effects on the outcome of these assessments. Nielsen et al. [2016] mention the opportunity to determine the criteria after the assessment, so the goal setting can be done afterwards. However, this also results in a less targeted assessment process. In the light of the earlier mentioned premature convergence by Westerveld and Hertogh [2010], the positioning of certain steps in the decision-making process plays an important role.

2.5 COMPLEXITY OF DECISION-MAKING DURING FED

Considering the discussed importance and opportunities of FED in MR&R projects, it seems evident all organizations aim to prepare their projects accordingly. However, utilizing the benefits of FED and achieving the stated performance requirements is not that straightforward as scientific literature may present. As discussed in the previous section, decision-making regarding the configuration of MR&R projects is a complicated process. The content and timing of the decisions has impact on the outcome and decisions tend to influence each other and the process. This section will therefore focus on the way achievement of the requirements during the FED is influenced by the process and its content.

Complexity in projects is considered as the number and type of elements and the number and type of relationships between these [Westerveld and Hertogh, 2010]. Hence, increasing levels of complexity often means it gets more difficult to unravel the effect of influencing one component; which leads to increased uncertainty [Salet et al., 2013]. As discussed in section 2.4.1, the opportunity to create value is highest in the early project stages. However, these stages are also characterized by the highest levels of uncertainty, as necessary information to base decisions on is rather limited [Samset, 2009]. The combination of complexity and uncertainty during the FED stages makes a decision-making on MR&R project configuration a complicated process. Decision-making during FED phases is therefore often questioned, as decisions are based on rather limited information and related assumptions [Welde and Volden, 2018].

2.5.1 Elements influencing the configuration of MR&R projects

To assess the decision-making on MR&R project configuration it is key to find out what elements do influence this process. Within the context of MR&R projects and the related decision-making on the configuration of projects, the earlier discussed processes of Šelih et al. [2008]; Nielsen et al. [2016] revealed complexities which need further elaboration. As the aim of this chapter is to reveal the present challenges related to FED decision-making, these findings will also function as the glasses through which the cases in the next chapter will be analyzed. While the research by Nielsen et al. [2016] already compared 43 articles on decision-making support tools within MR&R projects, it is plausible that most core elements which influence and therefore complicate the decision-making are incorporated. The results of this literature based analysis will be the first representation of the process which go on in the earlier mentioned black-box in figure1.1.

Requirements

According to Nicholas and Steyn [2012], human made systems (e.g. projects) are designed to *do* something, as they have goals and objectives that are formulated by people. A goal is defined as an overarching statement regarding the purpose of a project, whereas objectives are more detailed and often measurable expressions of the purpose related to a certain aspect of the system. A goal is achieved by fulfilment of a set of project objectives, like economic benefits, financial profits and infrastructure mobility [Leijten, 2017]. These objectives can be split into more detailed and specific objectives, called requirements. In other words, requirements are the detailed criteria to which the system must conform when it wants to achieve the purpose and intended performance of the project [Nicholas and Steyn, 2012]. During the FED of a project or program, project purposes need to be made explicit and assessed to ensure that fulfillment will contribute to the organizations tactical and strategic performance [Samset and Volden, 2016]. Project purposes may go beyond tangible outputs and focus on how value creation is attained: which objectives and related requirements need to be fulfilled to create the intended value [Smith and Winter, 2010; Leijten, 2017; Martinsuo and Hoverfält, 2018; Liu et al., 2019].

Regardless whether the MR&R project comprises the renewal of a culvert in a remote village or encompasses the redesign of the entire flood defence system of the Netherlands, the public authorities in charge will be dealing with public goods [3] which are subject to public values. Examples of public values are: accountability, integrity, safety, functionality and sustainability. While public organizations in MR&R projects embody the role of a client, collaboration with society and market in projects is inevitable [Kuitert and Volker, 2016; Koops et al., 2017]. Logically, market parties aim to achieve different objectives which ensure the continuity of their business operations [Cheung and Chan, 2010; Yu et al., 2018]. Difficulties arise when public and private values of the involved stakeholders need to be transferred into practice. Complexity of projects is determined by the defined and aimed creation of value inside a project [Leijten, 2017]. These values are reflected in certain measurable requirements like costs, time, scope, quality and safety [Koppenjan et al., 2011]. From everyone's own perspective, all their values are desirable to be incorporated into the project. However, the values tend to have an ambiguous and conflicting character [de Bruijn and Dicke, 2006; Bozeman and Beck Jørgensen, 2007; Reynaers and de Graaf, 2013; van der Wal, 2008] and may lead to conflicts as different involved actors deem certain values more important than others [de Graaf and Paanakker, 2015; de Graaf et al., 2016; Koops, 2017; Kuitert et al., 2019].

Concerning the necessity of public-private collaboration for the development of a MR&R project, it is key to create consensus among the involved stakeholders. A situation where every stakeholders' interest is facing the same direction leading to a unanimous support for project plans is considered a fairy tail in the world of infrastructure development. Research by De Bruijn et al. [2010]; de Bruijn and ten Heuvelhof [2008] state that opposing values will always create tension, where decision makers have to find a solution which will be considered acceptable in everyone's eyes. Value creation in MR&R projects demands acknowledgement and understanding of values in place [Liu et al., 2019]. Starting with a determination of present values and corresponding requirements during the FED, can therefore

3 Public goods are characterized by their non-excludability i.e. no one can be excluded from consumption, and non-rivalry i.e. consumption of an individual doesn't affect the availability of the good to others [Clarke, 1964]

potentially contribute to improved project performance [Cooke-Davies, 2009]. Despite the complexity of decision-making among conflicting values, incorporating all present requirements would simply be too complex [De Bruijn et al., 2010]. Relative importance can be attributed through linking a weight to all requirements . By assessing the relative value of all requirements, a distinction can be made which may ease the decision-making process [Nielsen et al., 2016]. However, as mentioned earlier, the FED phases are characterized by high levels of uncertainty due to the lack of information on critical decision-making elements. Determining, defining an weighing of requirements are logically subject to the amount of present information. If an asset diagnosis shows that the condition is lower than the minimal safety requirements, the importance of safety relative to other requirements is assumed to increase. This may affect decision-making on the to-be-executed MR&R interventions and related project configuration.

State of the assets

Assets which qualify for a potential renewal or replacement are picked based on the end of their initial estimated lifetime determined during the design decades ago [van der Vlist et al., 2015]. However, the stress on these assets could differ significantly from the former norms and related calculations which were based on estimated user and degradation rates [Levinson, 2018]. Absence of data confirming the exact state of an asset causes a risk with a related uncertainty in terms of decision making on the right intervention method. To fill the gap of lacking data, inspections for asset valuation are necessary [Glendinning and Hall, 2011; Schraven et al., 2011].

Design alternatives

Closely related to the effect of intervention measures is the applicability of the discussed intervention methods. Given the state of an asset, as show in figure 2.2, an intervention method is only feasible during certain conditions. Adequate timing is therefore essential. Too early renewal or replacement may lead to insufficient use of investments, whereas too late interventions may lead to loss of societal benefits like safety [van der Vlist et al., 2015]. Life span information is therefore one of the inputs for the decision whether maintenance, renewal or replacement is necessary. However, life span can be interpreted in several ways. The most commonly used types of life span are [Hermans, 1999]:

- **Technical life span** - The period that (a component of) the asset can physically perform the required performance.
- **Functional life span** - The period that (a component of) the asset can fulfill the function for which is was initially built.
- **Economic life span** - The period that (a component of) the asset cannot be replaced by an alternative with lower or equal operational costs.

Inspections assessing the state of the asset mainly provide information regarding the remaining technical life span of asset [Thuvander et al., 2012; Levinson, 2018]. Next to the actual state of the asset, determination of the remaining functional and economic life span is dependent on the stated requirements and present alternatives, respectively. Decisions whether to maintain, renew or replace an asset (as discussed in 2.3) are therefore based on numerous trade-offs.

Resources

However, opportunities to carry out MR&R projects are bounded to the presence of necessary resources. Resources occur in various ways, like finance, human capital, raw materials and facilities [Azim, 2010]. Main challenge arise related to the allocation of present resources among the ongoing (MR&R) projects within an organization. For example, setting up MR&R projects demands significant organizational effort as many different levels of the organization need to be incorporated, together with the amount of organizational units involved and the variety of occupational specializations present to carry out the tasks within a project [David Baccarini, 1996]. As resources may be deployed by multiple assets, cross-asset resource allocation can be used to distribute resources based on simultaneous prioritization of utility [Abukhalil et al., 2019]. Complexities regarding resource allocation are closely related to the earlier discussed complexities of present requirements and the state of the assets. When a public organization demands short MR&R intervention times due to the effects on national, regional and local

traffic flows, more capital and research capacity may be invested to find and execute a suitable solution to renew or replace an soon-to-be outdated bridge. Nonetheless, every euro and man hour can only be spent once, which reduces the ability of other assets within the portfolio of the public organization to use available resources.

From a primary financial perspective, the determination of the cost-effectiveness of MR&R works is often done through conducting an Life Cycle Cost Analysis (read: LCCA) [Hassanain and Loov, 2003]. Since MR&R challenges go beyond monetary constraints, assimilating the challenges of aging infrastructure from both a technical as a organizational perspective provides an improved overview of the the boundaries of resource allocation. By analyzing and incorporating the research domains which expose constraints of developing a MR&R project, the translation of objectives and values into final project configuration plans is intended to be more realistic and fit-for-purpose [Thiry, 2004; Koops et al., 2017]. Accordingly, the feasibility of proposed projects is intended to increase.

Configuration methods

Smith and Winter [2010, p. 47] stated that:*"To achieve success, we must first ensure we are not merely managing projects right, but also managing the right projects."* As the scope of MR&R projects sometimes covers multiple assets, this complexity is related to the project configuration options to chose from while deciding upon a composition of MR&R projects. Major question related to project configuration is: "What is inside the scope of a project?". Related projects often start with the simple idea of maintaining, renewing or replacing an asset, but can become very complex as they have to deal with different purposes and interests in an ever changing environment [Salet et al., 2013]. Outlined challenges of conflicting values and numerous technical hurdles shape the environment of renewal and replacement projects. Main goal of the MR&R configuration (which takes place in the early phases of a project life cycle), is to configure a project in such a way that is uses the present opportunities which support the successful development during the subsequent project phases. In order to make MR&R projects a success, a lot of hurdles in the form of uncertainties and complexities have to be dealt with [van der Vlist et al., 2015]. Instead of finding suitable solutions to pass these hurdles, the configuration of a project aims at providing the right conditions to deal with these obstacles and simultaneously commit to the pre-determined objectives and values and use the opportunities given the present MR&R challenge. In the case of MR&R projects, which are characterized by ill-structured problems, dynamic conditions, time pressure, multiple stakeholders and technical complexity, decisions (regarding the configuration of MR&R projects) are sometimes insufficiently fathomed by the authorities [Chen and Bai, 2019].

Opportunities for clustering arise as a consequence of the size (i.e. amount of outdated assets) of most MR&R challenges public authorities encounter, in combination with the forthcoming broad set of objectives and values. Options to take measures in the case of a public authority often goes beyond undertaking one single intervention on an outdated asset, to improve the overall performance of its network [Burns et al., 1999]. However, to configure a MR&R project appropriately, it should not only consider the challenges provided by the body of aging assets and the objectives and values present. Another and indispensable element of the FED process are the clustering options itself [Moghaddam and Nof, 2015]. Infinite combinations of projects can result to different configuration sets, circumscribed within the physical and financial boundaries of an organization [Archer and Ghasemzadeh, 1999]. Configuration of MR&R projects can be done in the following ways:

- **Project-based:** A project or a multitude of projects carried out in isolation and managed singularly [Evaristo and Van Fenema, 1999]
- **Program-based:** A set of projects that are managed collectively by one team which are considered to bridge the gap between project delivery and organizational strategy [Van Der Merwe, 1997; Lycett et al., 2004]. Programs exist in multiple manners, distinguished by Pellegrinelli [1997] into:
  - **Portfolio:** Grouping of projects which are relatively independent but share a common theme (resources, knowledge, skills, infrastructure etc.), which enables efficiency and performance improvements.

- **Goal-oriented:** Enable the development of one-time initiatives outside the existing organizational standard operating procedures, to develop new and uncertain business strategies without knowing the exact implementation process nor a certain outcome in advance.
- **Heartbeat:** Enables revolutionary improvement of existing systems, processes or organizational change. The heartbeat programs create value through the reconciling of contradicting requests emanating within (different parts within) the organization, which are grouped into projects and should deliver improvements to the core system without disruptions to the regular operations.

The decision for a certain configuration also marks the end of the FED 2 phase, as shown in figure 2.9. The chosen configuration will be worked out more detailed in the consequent project phases. Important note regarding the decision of a program-based approach must be made, while configuration does not lock the decision regarding the procurement of individual the MR&R activities. Achievement of the intended purposes of the chosen configuration is to be decided outside the scope of the FED, whereas the configuration sets the boundaries to achieve such objectives.

2.5.2 Process leading to the configuration of MR&R projects

Regardless of the decision of the FED on a final project configuration, it is key to align the FED process design with the desired outcome: a project configuration that includes present complexities, uncertainties, opportunities, objectives and values [Bosch-Rekveldt et al., 2011]. For example, a beforehand desire of a public authority is to stimulate circularity by re-using building materials. The process in preparation of a MR&R project is however decided to be single focused, which means that the investigation of the current conditions, determination of important criteria and the decision process regarding the configuration is only taken from the perspective of one single asset. Availability of building materials which can be re-used will logically increase if this perspective shifts from one single asset, to a cluster of multiple assets [Geldermans, 2016]. On the contrary, it will potentially take more time to investigate the opportunities for the re-use of used materials for a set of assets compared to the opportunities from a single asset perspective. Investigation regarding the different process design options is therefore key, to explore the potential opportunities and threats to create an improved alignment between the current conditions, resources, requirements and configuration options in a MR&R challenge.

Composition of the process

Comparison of the two FED processes by Šelih et al. [2008]; Nielsen et al. [2016] shows that given the different purposes of the processes, the composition of the process differs as well. de Bruijn and ten Heuvelhof [2008] state that the the composition of the problem which needs to be solved seems to change over time. The decision whether to incorporate certain aspects during the FED can have varying reasons. Some may be strategically, as certain decisions are less relevant during the early phases of a project, like contractual composition or detailed design considerations.

Another reason may be less well-taught, as decision-making considerations are simply forgotten. Literature refers to these unforeseen elements as 'unknown-unknowns', which make the possible outcomes of decisions unknown [Sperry and Jetter, 2009; Nicholas and Steyn, 2012; Schwindt and Zimmermann, 2015]. In contrast to known-unknowns, which are characterized as uncertainties, statistical inaccuracies and general fluctuations, these unknown-unknowns make it impossible to improve the accuracy of the information available to support decision-making [Leijten, 2017]. Decision-makers logically try to incorporate all relevant elements which relate to the present decision. However, not knowing what you don not know leaves room for uncontrollable uncertainty in decision-making. Besides thorough consideration of what elements actually influence the decision and including these in the decision-making process, the uncertainty related to a decision can not be influenced.

Scope of the process

On which level in the organization is the decision-making process taking place? Decision-making trade-offs on the configuration of MR&R projects of a local asset manager logically differ from the decisions made by the Board or an other organizational overarching division. Scope of the decision-making

is therefore considered an important element, as this determines the context where requirements, resources, conditions and configuration options are to be balanced [Salet et al., 2013; Nielsen et al., 2016].

Sequence of process steps

Alignment of the objectives and values of a MR&R challenge seems obvious, but needs thorough consideration [de Bruijn and ten Heuvelhof, 2008]. Therefore, the sequence of the different decision-making moments needs to be aligned with the relevant composition of that moment. Premature convergence; choosing a solution (too) early in the process and thereby excluding many other options at that point of time, is undesirable [Westerveld and Hertogh, 2010; Bakker et al., 2016]. To emphasise the issue, starting the FED with a decision on the preferred design alternative before having an idea of the asset conditions may lead to difficulties and undesirable outcomes as the decision lacks certain background.

2.6 CONCEPTUAL FRAMEWORK OF THE FED OF MR&R PROJECTS

Altogether, the complexity of decision-making is considered to be influenced by various elements and process design considerations. The problem of configuring a project (portfolio) arises from the everyday dilemma faced by organizations in finding the best possible way to distribute a limited budget among candidate projects to fulfil the needs of the organization [Carazo, 2015]. Complexity of determining a suitable intervention measures raise as the considerations have to be made on a larger scale. Given their interconnectedness with the present day infrastructure network, their technical specifications, present resources and configuration opportunities, a plan for dealing with a set of soon-to-be-outdated group of assets is not easily made. Based on the challenges, objectives and opportunities to link both, an overview of the opportunities for asset owners to align the status quo to their required is be developed in figure 2.12.

Important aspect of the conceptual framework is the visualization of the interrelatedness between the several elements which influence the decision-making. These elements together shape the substance of the decision-making challenges during the FED of MR&R projects. The relations between the several elements which influence the decision-making will be clarified with a direction and an explanation in chapter 4, based on the empirical insights. Other important aspect of the framework are the crucial process design elements regarding the scope, composition and sequence of the decision-making process. These are not included in the conceptual framework, as this is largely dependent on the context of the MR&R challenge a public organization is facing. Analysis of several MR&R cases will provide this input, based on the dynamics as shown in figure 2.12.

2.7 CONCLUSION

As a consequence of the baby boom in asset construction around the 1960s and 1970s, the forthcoming decades will largely be about maintaining, renewing and replacing these assets [Hertogh et al., 2018]. Besides the technical challenges, there are societal, financial, legal, environmental, organizational and time dynamics which further complicate the operating activities of public authorities in the transportation infrastructure domain [Westerveld and Hertogh, 2010; Pellegrinelli, 2011]. Compared to greenfield, MR&R projects are considered more complex due to their tangible and intangible linkages with existing systems [Bosch-Rekveldt, 2011]. Regardless of the naming and framing of the preparatory phases of a project, a sound FED is avowed to be critical for ultimate project success [Batavia, 2001; Bakker, 2008; Smith and Winter, 2010]. By answering questions like: who, why, what, which way, wherewithal and when, the contours of a project are outlined [Ward and Chapman, 2008]. Since the aim of this chapter was to create a theoretical background on these dynamics and related challenges of the FED in MR&R projects, the following sub-question was answered:

Sub-question 1 *- "What aspects cause the complexities related to the decision-making on project configuration during the FED of MR&R projects according to literature?"*

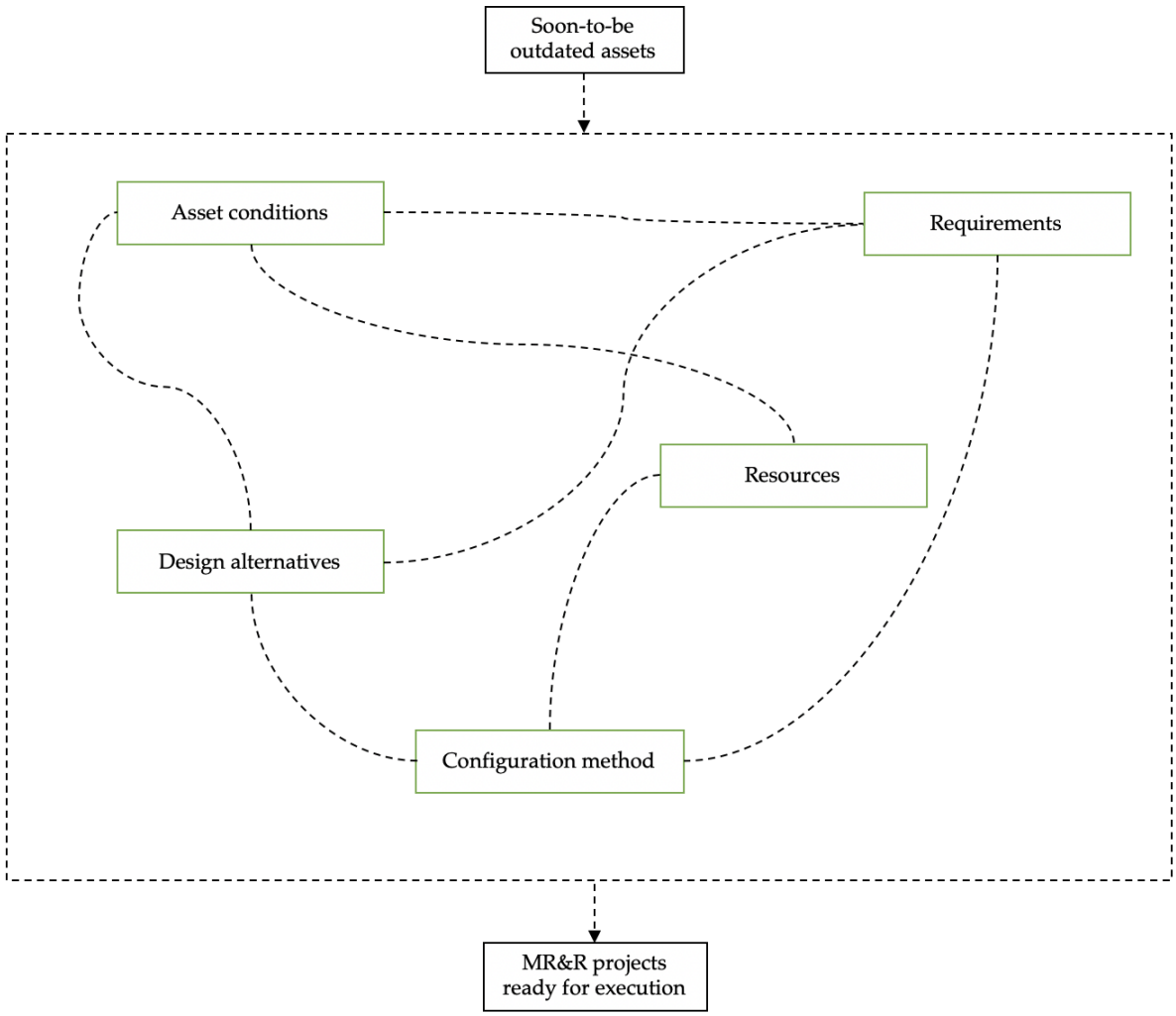


Figure 2.12: Conceptual framework of the factors which complicate decision-making during the FED of MR&R projects

Based on scientific literature on MR&R projects FED challenges and decision-making, it can be concluded that the complexities can be divided in substantive complexities and process related complexities. Substantive complexities are the decision-options elements which shape the body of the decision-making process. These options consist of the **present requirements, resources, configuration methods, design alternatives and the state of the assets**. Process related complexity is related to the **composition, sequence and scope** these decisions are made on. Timing of a decision is crucial. If decisions are made (too) early in the process, room for solutions which meet the requirements, take present resources into account and deal with the current conditions and configuration opportunities in a fit-for-purpose manner will be bounded [Westerveld and Hertogh, 2010]. On the other side, if decision-making takes too long, this will hamper the development of the project. Therefore, it is key to investigate how these dynamics occur in practice. The cases in chapter 4 will be analyzed to provide empirical interpretation and potential additions to the listed complexities. By raising the question:*"What are the main challenges related to the decision-making regarding configuration of MR&R projects in practice?"*, the content of the dynamics should become clearer. As reality is often in poignant contrast with theory, diving deeper into the FED process design of several MR&R projects is therefore intended to create a more pragmatic overview of the FED. The list of substantive complexities may be larger and the cases should shed light on their process design and the related consequences of their decision-making process.

3 CASE ANALYSIS

Different public authorities in the Netherlands are currently having their MR&R challenge on the agenda. In general, every public authority has to deal with regular maintenance of their assets. However, as the situation currently exceeds the regular maintenance objectives and deals with the end-of-lifetime of numerous assets, a procedure needs to be developed which includes a combination of characteristics from maintenance and new construction projects. To get a better view on the way different public authorities tackle this challenge and how they do design their process, MR&R cases are explored to get a practical view on the present challenges.

The empirical analysis is split up by an individual case part and a comparative part. First, project details are presented to gain insight in the purpose and context of the cases. As the objective is to create a decision-making framework which is generalizable for all public authorities within the transportation infrastructure sector, multiple cases are selected of different actors with varying sizes and challenges. In this chapter, summaries of these individual case analysis are presented which are based on the extensive case analysis in Appendix D. Next to the analysis of project related documents, semi-structured interviews with involved persons are held to get improved insights in the dynamics of the investigated cases. Their visions on the project and the related complexities are included in the analysis. Detailed information about the interviewees can be found in Appendix B. In the next chapter, the comparative case analysis will be executed. This part integrally analyzes the cases on the stated complexities related to the decision-making on project configuration (as discussed in section 2.5 and provides conclusions on the main complexities which appear in practice. These insights will function as input for the determination of a suitable decision-making framework and the consecutive development of the framework itself in the next chapters.

3.1 CASE SUMMARY 1 – VENR RIJKSWATERSTAAT

In this section, the VenR challenge (freely translated: Replacement and Renewal Challenge) will be summarized. As a consequence of the the mentioned baby boom in civil structure construction in section 2.3, a nation-wide challenge in terms of asset conservation emerged. In order to manage the aging of its assets, Rijkswaterstaat started the nation-wide VenR challenge in 2008. This challenge lists all assets of which is known they are reaching the end of their technical lifetime and need a MR&R intervention in the (nearby) future. Since VenR consist of various kinds of assets all across the Netherlands, all organizational regions and departments of Rijkswaterstaat are involved. This creates interesting dynamics during the development of the challenge and within the organization, which are discussed in detail in the section A.1 and summarized in table 3.1. At the time of this research, VenR was already going on for a couple of years. The input of this analysis comes from both exploratory as in-depth interviews with involved persons on multiple organizational levels. Thereby, related documents as plans of action, bi-annual progress reports and evaluations are used as input for the analysis.

3.1.1 Main acknowledgements

The VenR case brightly reveals the complexity a public authority is facing with regard to the aging of its assets. From an overarching perspective, the Board of Rijkswaterstaat faces a challenge which is shaped by a severe magnitude, consisting of assets a variety of different sizes, materials, purposes, locations and conditions. The chosen process design, to deal with this challenge and configure the projects accordingly however raises some questions concerning the functioning of the FED process.

Case	Vervanging en Renovatie (VenR)
Organization	Rijkswaterstaat
Duration	2008 - ?
Context	Nation-wide MR&R challenge
MR&R elements	Wide diversity of assets like bridges, tunnels, locks, viaducts and noise barriers
Budget	€650 M / year
FED procedure	1: Research program assessing the global state of all assets in the organization 2: Regional analysis determining the state of their assets 3: Division of MR&R- needy assets in Tranches (a portfolio), which embody a group of assets which need a MR&R intervention in the nearby future. 4: Detailed condition assessments and consecutive determination of intervention alternatives is carried out individually per (element of an) asset 5: Decision on preferred intervention alternative 6: Execution
Configuration methods	1 (element of an) asset = 1 project
Process coordination	Included in regular activities of regional divisions, support by special VenR team
Main requirements	Strong focus on improvement of organizational processes
Main complexities	Sequence of process steps Inefficient bundling of VenR activities Resource allocation Composition of project teams Coordination of execution planning

Table 3.1: Case summary 1 - VenR Rijkswaterstaat

As interviewees RI1, RI2 and RI3 all mentioned, the complexity of the VenR process increases due to the fact that the MR&R activities are merged into a certain Tranche. Clustering the projects in this Tranche has the appearance of a portfolio approach [Unger et al., 2012; Carazo, 2015]. However, to use the opportunities of this portfolio, the Tranche should also be coordinated accordingly [Pellegrinelli, 1997]. Currently, the entire process as shown in figure A.3 shows shifts in the level of coordination between an asset, regional and organizational perspective. Having an organization wide portfolio of assets which all demand a MR&R intervention, raises the opportunity to look for certain asset transcending configuration possibilities. Merger of projects within VenR could have positive effects on resource allocation and demands, coordination opportunities and alignment with ongoing other projects within or outside the organization [Koppinen and Rosqvist, 2010]. So far, the only configuration which includes more than one project is the merger of 9 tunnels in the Province South Holland.

To manage the Tranches, organizational overarching coordination could be useful regarding the planning of the execution of MR&R activities. While the impact of MR&R activities logically has impact on the traffic flows and nuisance for the surroundings, trade-offs have to be made regarding the planning of the execution. By currently working on a first-come-first-serve basis, potential negative consequences on the present requirements and values are harder to oversee and prevent. Whether this coordination has to be done by the appointed VenR team is questionable, while the execution is also interrelated with projects outside the VenR scope.

Therefore, a pivotal role for the Board of Rijkswaterstaat which oversees the entire set of activities within Rijkswaterstaat is reserved. Besides, the current process design raises questions regarding the sequence of the decision-making moments and content of the process (as shown in figure A.3. Currently, the detailed intakes of all assets take place in the beginning of step 4 of the VenR process. As suggested by Program manager RI2, the information of the intakes could also be retrieved during the region analysis in step 2. Shifting the sequence of these intakes would result in the absence of a time consuming preparation of step 4, before the scope of the project can be determined.

To conclude, balancing resources and requirements within a scope of dozens of MR&R projects is without a doubt a challenging assignment. Analysis of VenR raises numerous questions regarding the content, sequence and scope of the process design. Comparison with the other cases in this chapter will

provide the opportunity to mirror the analyzed VenR process and related decisions in multiple contexts. These observed trade-offs are therefore of importance regarding the development of a decision-making framework which is usable for MR&R project configuration within the transportation infrastructure sector.

3.2 CASE SUMMARY 2 – KARGO RIJKSWATERSTAAT

In this section the KARGO (freely translated: Large-scale maintenance of civil structures over the Amsterdam-Rhine Channel) program will be summarized. Compared to VenR, this program covers a fixed project configuration spread over just two regions of Rijkswaterstaat. However, this program also had its difficulties throughout the project life cycle. One of the main complexities in this program, was to determine whether a bridge had to be renewed or replaced. Collaboration between client and contractor played an important role in these trade-offs. Afterwards, question marks were placed regarding the timing of these decisions to either renew or replace a bridge. Given the fact that KARGO was a configuration of eight steel arched bridges, it is intended to provide a more detailed perspective on several grounds and opportunities to merges multiple assets into a project or program. The case description is based on semi-structured interviews and the ex-post program evaluations. The comprehensive overview of the analysis is available in section A.2 and summarized in 3.2.

Case	Kunstwerken Amsterdam Rijnkanaal Groot Onderhoud (KARGO)
Organization	Rijkswaterstaat
Duration	2010-2016
Context	Merger of 8 bridges into one program, based on their corresponding location, size, material and need to be lifted
MR&R elements	Renewal and replacement of eight steel arch bridges crossing the Amsterdam-Rhine Canal
Budget	€152,2 M
FED procedure	1: Determination of MR&R demand of multiple bridges 2: Organizational decision to merge eight bridges into the KARGO program 3: Objectives setting and preparation of tender procedure 4: Selection of preferred contractor 5: Execution of MR&R works
Configuration methods	Eight assets in one program
Process coordination	Collaboration between two regional divisions and one organizational division in one team
Main requirements	Strong focus on intended benefits of combining multiple similar assets. in one program
Main complexities	Uncertainties in the conditions Size of the program Working with outdated technologies Close collaboration of three Rijkswaterstaat divisions Timing and content of decision-making

Table 3.2: Case summary 2 - KARGO Rijkswaterstaat

3.2.1 Main acknowledgements

Merger of eight steel arch bridges which cross the same canal in one program, show the opportunity of MR&R configuration which is relatively unique and logical at the same time. Unique while the program crosses two different Rijkswaterstaat regions, but logical as the conditions of the present assets show great similarities and all bridges required a significant elevation to support inland shipping. Exactly these similarities in size, material, location and elevation demand predominated the final decision to cluster the bridges in one program coordinated by one composed team. This decision finally resulted in the intended positive effect of learning-by-doing, which had significant impact on the progress, costs, risk management and quality of the program. However, the early-on decision to merge these bridges

as one program also led to some complexities.

Management of eight projects in one overarching program requires significant coordination effort compared to the management of one single project. Since all related project life cycle phases of the different bridges were intermingled in the program, coordination and management of the program required significant effort. Thereby, the incorporation of two regions in one team resulted in difficulties regarding the alignment towards the overall program objectives.

Besides, the fact that the program was focused on existing assets resulted in some additional complexities. The use of the chosen Design and Construct contract form was relatively new and labeled as innovative at that time. The distinction between the bids of the interested contractors were partly based on calculations and related trade-offs regarding the execution works. This indicates a difference between greenfield and brownfield projects, as the option to either renew or replace an asset has significant consequences for the final bid. Having the freedom to decide wheter to renew or replace an asset makes it hard to compare the bids of the contractors, compared to greenfield projects which have more certainty in their scope. Reality showed that making renewal or replacement decision in the early stages of a projects makes little sense and take relatively long. In the end, detailed information on the actual assets conditions is revealed once the contractor starts with its MR&R activities. Making extensive calculations without this critical information is therefore of a relatively low value. This insight marks an important lesson for future MR&R projects, as significant time and costs can be saved with postponing a decision regarding the exact content of the MR&R interventions to a later stage of a project.

Overall, the KARGO program created useful insights in the related dynamics of a MR&R program and related complexities of the decision-making. The idea behind the made decisions and the consequences of it pinpoint important trade-offs while determining the configuration in MR&R challenges in general. These will be incorporated in the comparison with other cases, which in the end will be input for the decision-making framework.

3.3 CASE SUMMARY 3 – PBK MUNICIPALITY OF AMSTERDAM

The first two cases by Rijkswaterstaat had assets spread all across the Netherlands. The next case is located within the city borders of Amsterdam, and is called: Programma Bruggen en Kademuren (read: PBK, freely translated: Bridges and Quay Walls Program) of the Municipality of Amsterdam. However, the reduction from national to a city perspective does not lead to an easier challenge. On the contrary, the proximity of MR&R-needy assets leads to unique challenges for the Municipality. To create an overview of the present challenges, multiple interviews were conducted with different persons involved in the PBK with technical, programming and managerial roles. In addition, project documents were consulted in order to get a comprehensive perspective on the ins and outs of the PBK. Important notice should be made, that at the time of this research the PBK was simultaneously in all project life cycles. This a consequence of the size of the program, causing an overlap in different project phases. The result of the comprehensive case analysis are presented in section A.3, of which a summary is presented in table 3.3.

3.3.1 Main acknowledgements

Having a city full of bridges and quay walls in critical conditions rises a immense challenge for the Municipality of Amsterdam. Being the capital of the Netherlands naturally results in a lot of stakeholders in a rather small area. Coming up with satisfactory decisions regarding the execution of their MR&R challenge resulted in the decision to create the PBK, which must guide the entire MR&R process in the right direction. Necessary intermingle of all project phases results in a rather complex process, combined with the challenge of maintaining, renewing or replacing 850 bridges and 200 kilometers of quay walls within the borders of one city. By following the 'safety first' principle, assets conditions form the base of the MR&R configuration. From there on, the possibilities to combine multiple assets in one

Case	Programma Bruggen en Kademuren (PBK)
Organization	Municipality of Amsterdam
Duration	2019 - ?
Context	City-wide MR&R challenge including significant amounts of deferred maintenance
MR&R elements	Renewal and replacement of 850 bridges and 200 km of quay walls
Budget	€150 M / year
FED procedure	1a: Technical assessment of asset conditions 1b: Second opinion on process and verdict 2: Determining potential measures 3: Framing consequences of measures 4: Trade-offs on measures against requirements 5: Decision-making on assets to undergo MR&R measures 6: Inform and communicate regarding decided measures 7: Execution of selected set of MR&R projects
Configuration methods	Seeking opportunities for: multiple assets = 1 project
Process coordination	Existence of program organization and coordination by Program Board, as new organizational division
Main requirements	Continuous trade-off between safety and accessibility
Main complexities	Size of the MR&R challenge Interrelatedness of assets Amount of involved stakeholders and related requirements Continuity of the process

Table 3.3: Case summary 3 - PBK Municipality of Amsterdam

project to reduce the negative effects on the involved stakeholders are searched for. Naturally, the PBK will have negative effects but by including assets which even have a remaining technical life span of around 20 years it intends to minimize the nuisance on the long term. The trade-off between program expenses and all forms of nuisance is therefore often made in favor of the citizens and entrepreneurs of the city. By doing so, the Municipality intends to keep all stakeholders as satisfied as possible in these difficult and uncertain times. Expanding the scope of the analysis with insights of other public authorities seems to provide new points of view and challenges regarding the decision-making during the FED of MR&R projects. While the Municipality of Amsterdam faces challenges of a different nature than Rijkswaterstaat, involvement of PBK in the comparative analysis is intended to develop a decision-making framework which is usable for all public authorities which face MR&R challenges.

3.4 CASE SUMMARY 4 – PMO PROVINCE NOORD-HOLLAND

Last but not least, the multi-annual maintenance program of the Province North-Holland will be analyzed. The reason to add the case to the analysis mainly resulted from the intention to get insights in the FED process of multiple MR&R challenges of various public organizations. While this case primary consist of maintenance and low renewal and replacement complexity tasks, instead of maintenance, renewal and replacement of larger assets, this difference is taken into account while comparing the cases in chapter 4. Another striking aspect of this case is the decision to execute the maintenance in geographically bounded parts of the province. Within every region one consortium of contractors is responsible for all maintenance activities which were previously managed by the Province itself. As this approach differs from the earlier cases, the idea and process behind this decision is deliberately investigated in A.4 and the summary is shown in table 3.4. The analysis was conducted by holding semi-structured interviews with the involved program managers and analysis of the program-related documents.

3.4.1 Main acknowledgements

In order to fulfill efficiency improvements to the conservation of the infrastructure in North-Holland, the Province decided to outsource MR&R activities with a low complexity in six regional service and maintenance contracts. This 'Gebiedscontract' (read:GBC) consist of a geographically bounded region

Case	Provinciaal Meerjarenprogramma Onderhoud (PMO)
Organization	Province of North-Holland
Duration	2015-2025
Context	Division of the entire province in seven regions, where contractors are responsible for the design, planning and execution of the MR&R activities
MR&R elements	Activities with a relatively low technical complexity like: de-icing, ecological roadside management and replacement of small-sized bridges etc.)
Budget	€45 M / year
FED procedure	1: Urgency of action was raised by Provincial Council regarding the state of the assets 2: Decision to outsource low-complexity MR&R activities in a demographic manner 3: Preparation of the GBC **After FED:** 4: Selection of the appropriate contractor 5: Execution of GBC
Configuration methods	1 region = 1 contract
Process coordination	Supervision by Province, all design, planning and execution responsibility is with the contractor
Main requirements	Deliberate decision to outsource all activities and only supervise the MR&R activities due to opportunities to save financial and human resources
Main complexities	Size of the area Diversity of assets New role of the Province Short-term versus long-term benefits

Table 3.4: Case summary 4 - PMO Province North-Holland

where a contractor is responsible for all pre-determined MR&R activities for the next 10 years. Purpose of the GBC was to relieve the Province of its inefficient commissioning procedures of the relatively standard MR&R works (e.g. commodities). The complex and more expensive assets (e.g. specialties) were left outside this contract, as the content and complexity of the MR&R activities differ to a large extent. Besides, the Province still has the mandate to grant permissions regarding the planning of MR&R interventions within the GBC. Sharp formulation of the Province's requirements resulted in a GBC where the contractor takes care of all intended MR&R activities, but still has the freedom to plan and execute the activities (when permission is granted) whenever it suits the contractor. Provision of this freedom by the Province should lead to significant cost reductions, as contractors could execute the MR&R activities during off-peak moments. By doing so, allocation of resources can be done in an optimal way. Compliance of the contractor to the set agreements in the contracts is based on yearly quality reports and spot checks by the Province. In this way, the Province is still involved in the activities to a minimal extent.

All GBC's in the Province are currently going on and the first evaluations from both contractors as the Province's side were positive regarding the new way of collaborating. The Province has not decided yet whether it will pursue with the GBC after the termination of the contracts. Going back to the traditional way and commissioning all MR&R activities individually however does not seem to have the same benefits as the current use of GBC's.

3.5 CONCLUSION

The intention of the individual case analysis of the four MR&R cases created a comprehensive overview of the challenges and opportunities related to the configuration of MR&R projects. All actors seemed to apply a different approach, based on the characteristics and present requirements related to the MR&R challenge. Comparability of the cases is an important point of discussion, as all cases had their unique challenges and different magnitudes. Further comparison of the different cases will therefore be done in the next chapter, based on the previously identified aspects which influence the configuration process.

4 CASE COMPARISON

After the individual case analysis, a comparison regarding the stated complexities which influence the FED decision-making is to be integrally contrived. By conducting a cross-case analysis, similarities and differences are highlighted which jointly shape an overview of complexities during the FED of MR&R challenges. In line with the developed dichotomy of context related complexities and procedure related complexities in chapter 2, the cases will be compared accordingly. The cases will be jointly compared on the presence of the complexity and supported by several examples of occurrence. First, the context related complexities will be analyzed. The interrelations between the context related complexities will be summarized in figure 4.3, clarifying the relations between the elements which interact during the FED. Next, the impact of the procedure related complexities on the FED are explained.

However, the identified complexities in chapter 2 were based on the present body of scientific literature regarding the FED and related decision-making of MR&R projects. Analysis of the cases showed that some additional aspect complicated the configuration in practice. These aspects are therefore be added to the analysis. Jointly, the theoretical background and the case comparison shape a comprehensive overview of the challenges public authorities face during the FED of MR&R challenges.

4.1 COMPLEXITY RELATED TO THE CONTEXT OF FED DECISION-MAKING

The secondary literature review in chapter 2 revealed that the context of the decision-making procedure regarding the configuration of MR&R projects during the FED was influenced by the asset condition, present requirements, availability of resources, design alternatives and the configuration methods. To get a view on the way these elements actually contribute to the complexity of the decision-making, the investigated cases will be integrally analyzed. In some situations, an element can influence the overall complexity in numerous ways, which will result in multiple explanations per complexity.

4.1.1 Main requirements

Analysis of four different cases of three public authorities stressed the earlier stated presumption that the purpose of a project often goes beyond tangible outputs and also aims to create value (in subsection 2.5.1. Nonetheless, value is catch-all which can be created in numerous ways and which is also strongly related to the background of an involved stakeholder [Cheung and Chan, 2010; Yu et al., 2018; Liu et al., 2019]. In various ways the underlying requirements influenced the complexity of the cases, which will be separately discussed.

Example 1 - Influence of organizational strategy (1)

In addition to the conceptual framework in figure 2.12, the investigated cases clarified an important element which was not included yet: **the organizational strategy**. While the MR&R environment is just one part of an organization, the overall strategy of an organization significantly influences the procedure by for example setting requirements for the MR&R challenges [AI2, personal communication, November 18, 2019] [Seaden and Manseau, 2001]. Programs are seen as an effective governance mechanism to provide a bridge between projects and organizational strategy [Shao and Müller, 2011]. Clarification of this connection is reflected in cases and their stated objectives. By way of example, 'Aligning organizational structure with present MR&R challenge', 'Seeking links between MR&R works and other internal projects' and 'Incorporate other ambitions of the municipality', are all part of the objectives of the investigated MR&R challenges of multiple public authorities.

Example 2 - Amount of requirements (2)

Evaluation of the design alternatives and configuration options in all cases was logically influenced by the stated requirements. The origin of these requirements however seemed to have different backgrounds. Next to the requirements which were imposed from above (given an organizational strategy), more categories seemed to be present. Subdividing the requirements of all investigated cases resulted in the following division, as presented in figure 4.1:

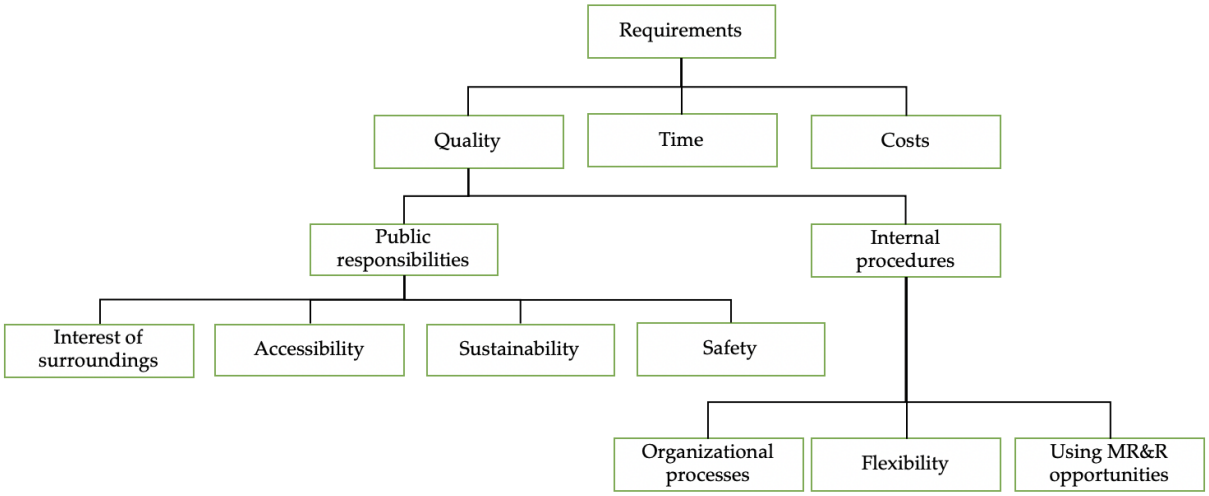


Figure 4.1: Subdivision of the requirements within the analyzed cases

Main observation of the four cases was the strong emphasis of qualitative requirements involved. As part of the traditional 'iron triangle', which requires a project to be under-budget, on-time and according to performance specifications [Atkinson, 1999; Toor and Ogunlana, 2010], the quality aspect tended to be the prime focus of these public MR&R projects and programs. Quality in particular, can be divided in both public responsibilities as internal procedures. Both will be explained separately:

Founded on the public role of the observed clients and their obligation to safeguard the public values, the following set of requirements were present:

- **Interests of surroundings:** Negative consequences of MR&R activities are inevitable. Air, noise, dust and vibration pollution and ecological, social and health impacts are one part of the social costs of construction projects [Çelik et al., 2017]. However, MR&R projects are often carried out to deal with the necessity of an intervention. Public authorities therefore have to find a balance between this necessity and the negative consequences to the surroundings [AI1, personal communication, November 1, 2019]. Examples of including those mitigating measures in the requirements of the MR&R cases were: 'Reducing GHG (Greenhouse gas) pollution' and 'Improving biodiversity'. Remarkable aspect was the presence of such requirements within the cases of the Municipality of Amsterdam and Province Noord-Holland.

- **Accessibility:** Second aspect of the social costs related to the execution of MR&R projects are the effects to the traffic and economic activities [Çelik et al., 2017]. While most assets are already part of the Dutch transportation infrastructure for decades, replacement and renovation would have significant impact on the local, regional and (inter)national traffic flows [Boes and Dorée, 2008]. Coming up with an approach for one asset can therefore create numerous problems for the surrounding regions [AI3, personal communication, November 18, 2019]. As assets may fulfill a critical function within the network of a public organization, requirements like: 'Reducing nuisance during MR&R activities - Limiting Vehicle Loss Hours (Dutch: VVU) , 'Minimize traffic disruptions' and 'Take care of a functioning city during the MR&R works' were part of the investigated MR&R cases.

- **Sustainability:** Public organizations serve the public interest, which results in more and more incorporation of sustainability requirements in the development of infrastructure projects [Hueskes

et al., 2017]. Organizations might focus on the mitigating measures which should reduce emissions during the construction activities or the re-using of building materials to lower the ecological footprint of a project [Lenferink et al., 2013b; Spraul and Thaler, 2019]. Sustainability requirements in the observed cases were for example: 'Sustainable commissioning - Take sustainability measures into account as criterion while selecting a contractor.' and 'Develop a sustainable living environment – Decision in line with local,regional and (inter)national ambitions, reducing environmental impact and operating circular'

- **Safety:** MR&R projects are different to greenfield projects, as they have to deal with the risk of structural deterioration [Yang and Frangopol, 2018]. Safeguarding the safety of the public is therefore the key requirement in all cases. This can be done by either reducing the potential chance of occurrence of an incident or by decreasing the potential consequences of an incident [Johansen et al., 2014]. The Municipality faced already several incidents related to their MR&R activities, like appearance of a sinkhole and downthrows of assets [AI1, personal communication, November 1, 2019]. Therefore, the cases included requirements which included both preventive as mitigating measures, like: 'Create an improved insight in the actual state of the assets', 'Mitigate the consequences of calamities', 'Operating safe - Guaranteeing safety (in the broadest sense of the concept) during MR&R activities' and 'Upgrading the asset state to the technical quality requirements'.

Besides, the analyzed cases paid sufficient attention to the internal procedures of the organization itself. Observance of the increasing amount of MR&R activities now and in the future, organizations are eager to find a way to include these projects in the current flow of projects. The way they are trying to do this, can be divided in the following groups of requirements:

- **Organizational processes** Based on the predictions as shown in figure 2.1b, the upcoming challenge regarding MR&R activities is going to increase in the coming decades [Nicolai et al., 2016]. Organizations like Rijkswaterstaat and the Municipality of Amsterdam traditionally had their main focus on greenfield projects and maintenance projects. The upcoming MR&R challenge is something completely new and requires a different approach as greenfield and regular maintenance projects [AI2, personal communication, November 18]. To align the increasing challenge with the current organizational structure requirements like: 'Improving co-operation with the serving Ministry', 'Aligning organizational structure with present MR&R challenge' and 'Simplification, innovation and optimization of preparation and execution of works to speed up and reduce nuisance of the MR&R work' are included in the observed cases.

- **Flexibility** Next to new working procedures, MR&R projects also demand new techniques to execute the challenges according to future demands, rules and regulations. These can be techniques related to planning, designing and construction. As public authorities acknowledge the need of these innovations to carry out the MR&R in an improved matter, room for innovations and research is to be created within the MR&R challenges. By including a certain flexibility in the way of working, room for improvements is likely to be created [Koppinen and Rosqvist, 2010]. Examples of these requirements observed in the cases are: 'Improve the predictability of corrective maintenance' and 'Flexibility – Having the opportunity to adapt the asset to future demands, rules and regulations'

- **Using MR&R opportunities** MR&R project are sometimes touching upon interfaces with other projects or programs which are going on within the organization. Using these opportunities may result in increased benefits for both projects [Nafi and Kleiner, 2010]. If for example, a quay wall is closed of for MR&R interventions, the Municipality sees opportunities to install underground waste collection systems [AI1, personal communication, November 18, 2019. By merging these projects, the Municipality aims to kill two birds with one stone. Examples of these requirements which seek these opportunities are: 'Seeking links between MR&R works and other internal projects', 'Incorporate other ambitions of the municipality (e.g. city logistics, car-free zones, sustainability and waste collection over water').

Example 3 - Conflicting requirements (3)

Conflicting requirements are everyday business during the FED of MR&R projects. When several stakeholders have conflicting (internal) ambitions and values, complexity of a project will logically increase [Bosch-Rekveldt et al., 2015; Leijten, 2017]. Thereby, (public) values tend to be conflicting and convergence is undesirable [Van Der Wal et al., 2008]. Normative considerations among the present values is therefore mandatory [Bozeman and Beck Jørgensen, 2007; de Graaf et al., 2011]. The Municipality of Amsterdam is however facing a diabolical dilemma. A lot of assets are characterized as 'critical' while being close to their end of technical life span. However, closing off the assets for MR&R interventions would lead to severe traffic infarcts in the city. What to do now? Interviewee AI1, which is responsible for the technical advise stated that arguing about safety is impossible [AI1, personal communication, November 1, 2019]. Certain assets are already partly closed off or temporary replaced by alternative bridges. On the other side, does Interviewee AI3 (who is responsible for the programming of the PBK) state that full closure of all assets which are in a 'critical' condition is simply not possible [AI3, personal communication, November 18, 2019]. This shows the complexity within one organization, as there is no good solution. To prevent these trade-offs in the future, Interviewee AI2 mentioned that financial performance of the PBK is less relevant, compared to the opportunities to reduce nuisance of MR&R intervention on the long run. This means, if a bridge or quay wall which still has a sufficient remaining technical life span of 25 years, it could still be renewed or replaced in order to prevent MR&R interventions in this region for the coming 50 - 100 years if it is in the proximity of an asset which undergoes necessary interventions. Lower valuation of program expenses is therefore an option to reduce the trade-offs between safety and other requirements [AI2, personal communication, November 18, 2019].

4.1.2 Asset conditions

Uncertainty regarding the exact state and remaining technical life span of the assets is a pivotal aspect in all cases. Assessing the asset's conditions beforehand seems necessary to provide some boundaries to a MR&R challenge [RI2, personal communication, November 22, 2019]. To what level these boundaries are set during the early phases is of great importance. Salet et al. [2013] states that most information which is gathered during the FED of a project, is associated only with the initially identified solution, rather than a systematic analysis of the problems, needs and requirements of a project. The first and main objective as observed in the MR&R projects, is prevention of collapsing causing a focus on a primary technical assessment of the asset conditions. Additionally, this results in a situation where this detailed information locks the decisions into this initially preferred concept, decreasing the opportunity to base decisions on other concepts[Salet et al., 2013].

Example 1 - Detail of condition assessments (4)

Absence of data confirming the exact state and related technical end of an asset's lifetime causes a risk with a related uncertainty in terms of decision making [RI2, personal communication, November 22, 2019]. To fill the gap of lacking data, inspections for asset valuation are necessary [Glendinning and Hall, 2011; Schraven et al., 2011].) Too early replacement or renovation would lead to capital destruction, though too late intervention could have disastrous consequences regarding the public safety [van der Vlist et al., 2015]. The necessary level of detail of these conditions assessments to base decisions regarding the configuration on, differed among the investigated cases. For example, within the PBK of the Municipality of Amsterdam, assessment of the asset conditions go beyond the remaining technical life span. The Municipality also encounters the traffic flows, purpose, location and material of the asset and proximity to residential areas in the evaluation of design alternatives [AI1, personal communication, November 1, 2019]. Same goes for VenR, where the special developed intakes for Tranche 4 assessed technical conditions, current and potential future use, sustainability opportunities and many more [RI2, personal communication, November 22, 2019]. However, expanding the decision-making criteria during the configuration trade-off with these additional asset conditions is not a matter of course. It took Rijkswaterstaat three Tranches to acknowledge the need of broader condition assessments [RI3, personal communication, December 10, 2019]. Besides, using the acquired data raises another issue which will be discussed in subsection 4.1.5.

Example 2 - Need of certain expertise (5)

Assets which qualify for a potential renewal or replacement are picked based on the end of their initial estimated lifetime determined during the design decades ago. However, the stress on these assets could differ significantly from the former norms and related calculations which were based on estimated user and degradation rates [Levinson, 2018]. Interviewee RI2 stated that: *"Renewal of assets is a craftsmanship"* [RI2, personal communication, November 22, 2019]. Determining the exact conditions and designing the reinforcement plans requires a broad set of skills and understanding regarding structural dynamics [Karydas and Gifun, 2006]. In the KARGO case, the initial idea of Rijkswaterstaat was that one of the eight bridges needed a replacement, whereas renewal interventions would suffice for the remaining cases. Without doubting the expertise of the persons who made this prediction, the final re-considerations after contract reward resulted in the decision to renew three bridges and replace five. Interviewee RI2 gave the following example: *"Calculations of reinforcements to the Breukelerbridge would result in an entire additional steel bow structure on top of the existing structure, to comply to the present laws and regulations regarding bridge safety. The costs of this renewal interventions compared to the additional technical life span did not outweigh the alternative of replacing the entire bridge. Therefore, the contractor and client decided to go for a replacement instead of a renewal [RI2, personal communication, November 22, 2019]."* The Province of North-Holland excluded the need of these kind of expertise during the FED, by simply outsourcing all of the asset-related activities to the contractors, which were assumed to have the expertise inside their organization to deal with the challenges in a fit-for-purpose manner [NH1, personal communication, November 25, 2019].

4.1.3 Resource allocation

Bluntly stated does the the presence of resources determine the room for manoeuvre in infrastructure projects to a great extent [Kim and Wilemon, 2002; White, 2012]. While resources are often associated with financial resources, projects are also dependent on the human capital, raw materials and facilities [Azim, 2010]. While all cases dealt with a broad variety of assets, (optimal) allocation of these resources was a major challenge.

Example 1 - Composition of teams (6)

Portfolio Manager RI1 of Rijkswaterstaat highlighted the scarcity of human resources given the current VenR approach explicitly during the interview. As all VenR projects consist of one asset, and every project needs for example technical, financial, or legal expertise, it is easy to image that this is causing problems. Experts are simply are scarcity and their knowledge is needed everywhere. Portfolio manager RI1 solved this issue himself by merging 9 tunnels which require the same expertise in one project [RI1, personal communication, September 23, 2019]. Same was done during the KARGO case, which merged the 8 steel bridges. By doing this, the knowledge of this expert can be used by all projects in one run, causing major advantages [RI2, personal communication, November 22, 2019]. Seeking such configurations seem to be necessary, as human capital is presumed to be scarce. If this complexity is overlooked by public organizations, MR&R projects may face severe delays due to the absence of necessary knowledge to further develop the project [RI1, personal communication, September 23, 2019].

Example 2 - Financial flexibility (7)

The clients in the analyzed cases showed an interrelation between the asset conditions and resource allocations as they wanted to have a view on the expected scope of the projects in order to reserve a budget for the upcoming MR&R interventions. However, the budget reservations of the PBK for example, consisted of a generic specification as a dichotomy of execution of replacement works and related research, incidents, enforcement, monitoring and innovation investments [AI2, personal communication, November 18, 2019]. KARGO on the contrary, had developed a fixed price cap of the MR&R interventions to which the interested bidders had to adjust their bids. In the end, the final costs were 38% higher than the set price cap as a consequence of the earlier discussed causes [RI2, personal communication, November 22, 2019]. Added value of determining the exact scope of the MR&R project to link a budget to it during the FED is therefore questionable, as this can also be done after

contract reward (like the two phased contracts of Rijkswaterstaat). On the contrary, there need to be a budget available to develop the MR&R projects. Room for uncertainty in budget reservations therefore requires a decision on the need to provide exact specification of a budget's purpose. Put differently, the decision to provide room for not precisely allocated or broadly formulated budget reservations goes hand in hand with the decision to embrace uncertainty [RI2, personal communication, November 22, 2019]. MR&R projects are simply uncertain. The ability to provide financial room to deal with these uncertainties is dependent on organizational-level decisions on accounting standards. Therefore, the scope (level of detail) and sequence of financial management plays an important role on the ability to go trough the FED procedure.

4.1.4 Design alternatives

Determining whether an asset has to be maintained, renewed or replaced is easier said than done. As mentioned before, existing assets exists of complex structural dynamics which may have faced severe deterioration rates, causing significant uncertainties regarding the exact state of an asset [Yang and Frangopol, 2018]. Public authorities in the analyzed cases seemed to deal with this uncertainty in totally different matters, all based on certain considerations and conditions. The decision to determine a design alternative, is often also dependent on aspects other than just the state.

Example 1 - Varying impact of design alternatives (8)

KARGO showed that if an bridge is to be renewed, significant technical condition assessments have to be carried out [RI2, personal communication, November 22, 2019]. On the contrary, Interviewee AI1 of the Municipality of Amsterdam stated that they do not have the time to assess all their assets to such a detailed extent. Therefore, decisions on the design alternatives are simply based on less information and also guided by other requirements [AI1, personal communication, November 1, 2019]. As the alternative routes on some locations in Amsterdam are limited, the effects of a MR&R intervention are significant. Sometimes the consequences of closing of a bridge can be so large, a temporary structure has to be placed, while the bridge or quay wall can simply not be excluded from the transportation network. However, using such temporary structures is considered as a sub-optional solution as it often can not bear the same loads and fulfill the complete functionality of the existing asset. Therefore, all interviewees AI1, AI2 and AI3 admitted that the decision on the design alternative in most cases would be replacement, as renewal would simply take longer and is therefore more expensive when encountering social cost in the trade-off [AI1, personal communication, November 1, 2019], [AI2, personal communication, November 18, 2019], [AI3, personal communication, November 18, 2019] [Çelik et al., 2017].

4.1.5 Configuration options

The last step in the FED procedure is the determination of the configuration itself. Given the challenges related to MR&R challenges, Chen and Bai [2019] mentioned that final decisions on a configuration are not that straightforward. Within the observed cases, the grounds to determine a certain configuration, the amount of configuration opportunities and the required effort to find configuration options however seemed to lead to sufficient challenges. Examples of the related complexities are provided in the following paragraphs.

Example 1 - Diversity of configuration grounds (9)

Dutch public authorities responsible for infrastructure often posses a great heterodiversity of assets like: bridges, tunnels and locks to water treatment plants, sheet pilings and quay walls. By expanding the scope of the decision-making on project configuration from one individual asset to a broader set of assets, additional grounds for project configuration can be encountered [Koppinen and Rosqvist, 2010; Kopmann et al., 2015; Marisa Padovani, 2017]. Instead of the state of the assets, the GBC in North-Holland were for example composed on their demographic characteristics and the scope of KARGO was decided upon a general MR&R need in combination with their corresponding steel bow

structures, length, location across the Amsterdam-Rhine Canal and demand to raise their height. By expanding the scope of the decision-making on MR&R project configuration, the decision-making gets more complicated, as more considerations have to be taken into account with the increasing amount of requirements [NH1, personal communication, November 25, 2019]. Conditions like traffic flows, purpose, materials, location, proximity to residential areas, are all examples of asset conditions which can be used in the decision on a project configuration [RI2, personal communication, November 22, 2019]. Configuration of renewal and renewal interventions based on corresponding conditions can reduce the complexity and uncertainty of projects which may have positive impact on aspects like: learning over projects, cost and time certainty, implementation of the supply chain concept leading to economies of scale and opportunities for creativity and innovation [RI2, personal communication, November 22, 2019], [NH1, personal communication, November 25, 2019], [TU2, personal communication, September 19, 2019] [Naoum and Egbu, 2016].

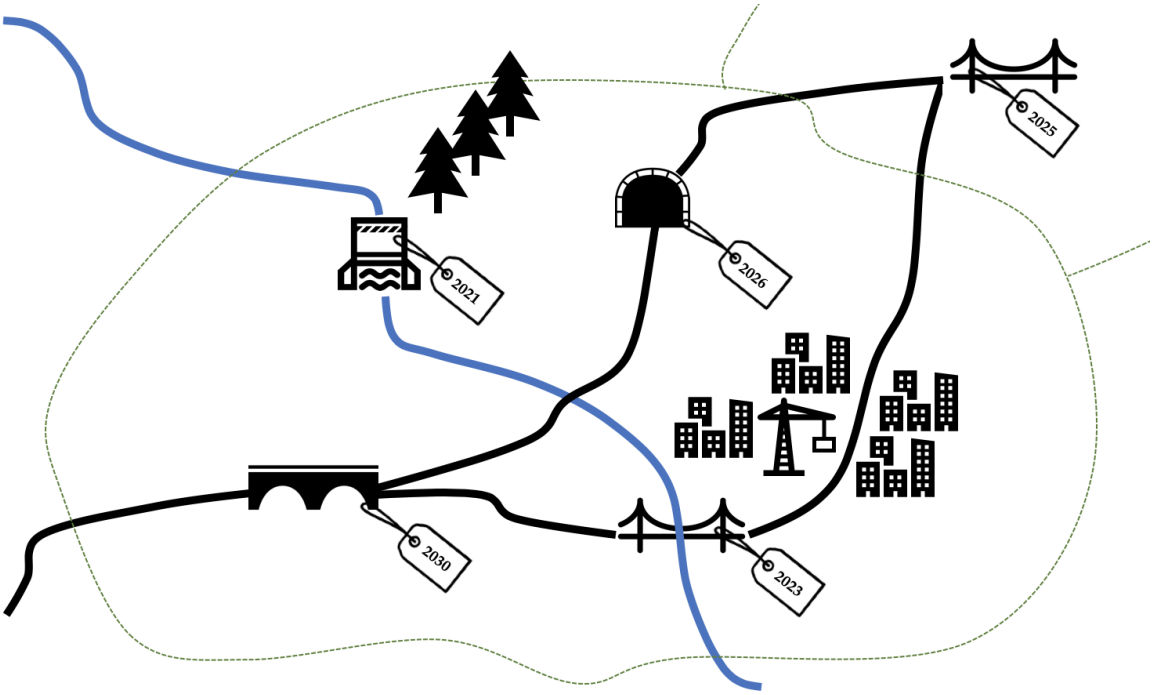


Figure 4.2: Simplified overview of a MR&R challenge

Altogether, an overview of the potential physical configuration grounds is visualized in one simplified image, shown in figure 4.2. By having unique characteristics, a varying end-of-lifetime and interactions with their surroundings within their area of control and overlapping soon-to-be-outdated assets outside their area of control, this simple image visualizes the amount of asset related challenges which have to be encountered during the MR&R challenge of an ordinary public authority.

Example 2 - Variety of configuration options (10)

As discussed in subsection 2.5.1, configuration of assets can be distinguished in project-based and program-based options [Moghaddam and Nof, 2015]. Within these options, an additional variety of sub-options exists [Pellegrinelli, 1997]. Given the amount of configuration options, public organizations face a situation where they have to make a decision among multiple opportunities which fulfil present requirements in a varying way [AI3, personal communication, November 18, 2019] [Van Der Merwe, 1997]. On one side, having multiple configuration options creates an opportunity to seek a way that meets the requirements in the most preferable way [RI3, personal communication, December 10, 2019] [Burns et al., 1999]. However, having multiple configuration options also complicated the decision-making procedure, as trade-offs have to be made among the alternatives. For example, the VenR Tranche 4 exist of 40 projects and more than 100 assets. Since the amount of configuration options within the entire Tranche is that substantial, it is perhaps easier to decide to not considered

other options than a project-based approach (like used in Tranche 1-3) [RI1, personal communication, November 23, 2019]. On the other side, if the amount of considerations is smaller, like in KARGO, the presence of a program-based configuration created opportunities to configure the assets in a more fit-for-purpose manner compared to eight separate projects [RI2, personal communication, November 22, 2019].

Example 3 - Necessary effort to find configurations (11)

Logically, the preparation of a program consisting of multiple assets is more time consuming compared to the lead time of one single project [Koppinen and Rosqvist, 2010]. Grounds for a specific configuration need to be found, evaluated and approved. The needed time to prepare a proper project or program may interfere with the needed urgency of action [Leung, 2016]. Various interviewees of VenR and PBK mentioned that the technical state of an asset sometimes requires immediate action, like the installment of (temporary) reinforcing measures. Time to seek for potential configurations with other assets is simply lacking, as (constructive) safety is at stake [RI3, personal communication, December 10, 2019], [AI2, personal communication, November 18, 2019].

4.2 UPDATE OF THE CONCEPTUAL FRAMEWORK

As a follow-up of the conceptual framework as shown in figure 2.12, figure 4.3 reveals the interactions between the different aspects which influence the decision-making. The interactions between the several elements are indicated with an arrow and brief explanation.

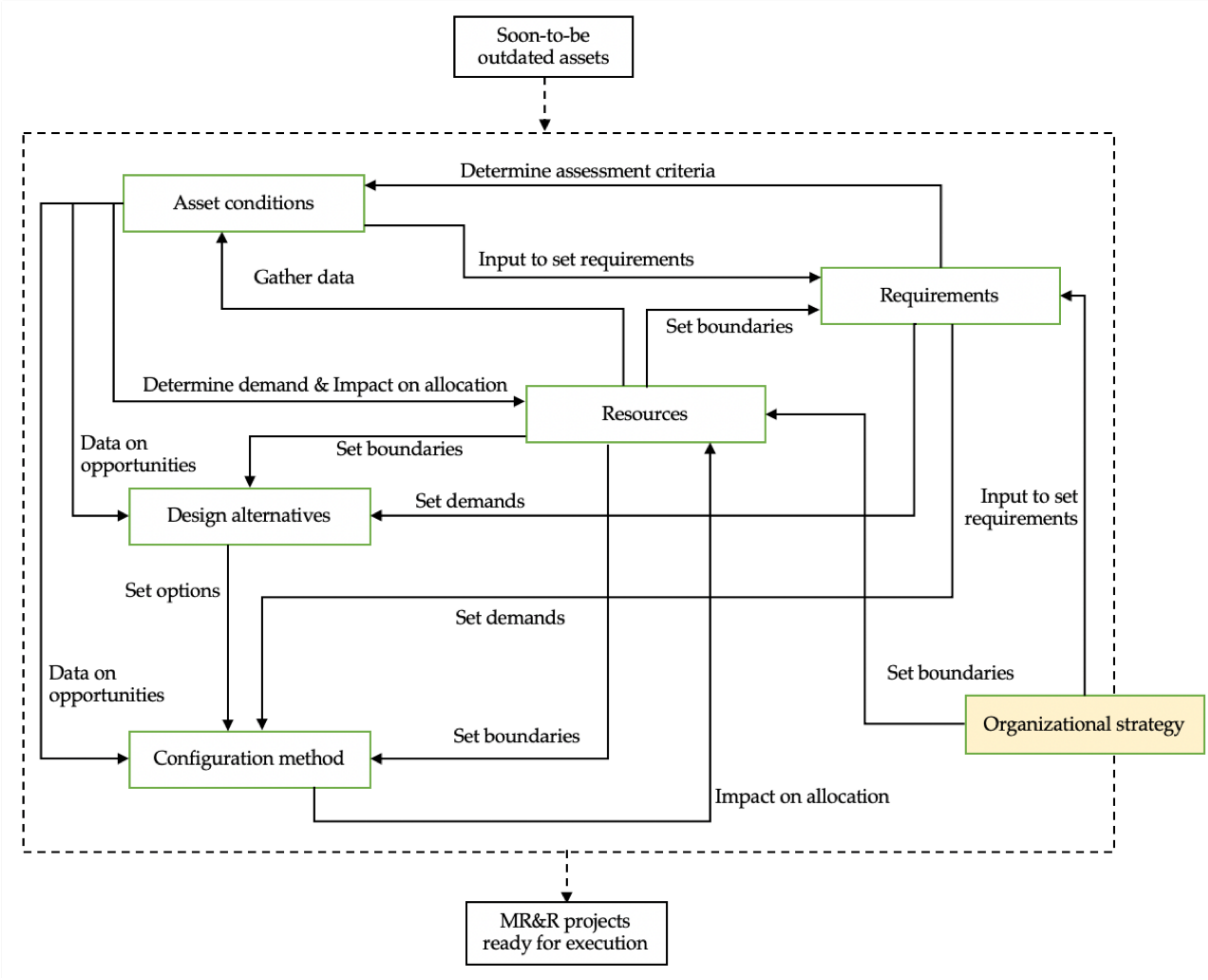


Figure 4.3: Updated conceptual framework of the elements which complicate decision-making during the FED of MR&R projects

Figure 4.3 can be seen as a visual summary of the cross-case analysis, which shows all of the potential interaction between the element which shape the complexity of the decision-making on MR&R projects. However, no visualization of the procedure related complexities are included in the figure. This does not insist these procedure related complexities are not relevant to the decision-making procedure. On the contrary, the design of a procedure is crucial to determine the extent in which these interactions of figure 4.3 are visualized. Therefore, the complexities regarding the composition, scope, sequence, coordination and agility of the decision-making procedure will be discussed in section 4.3.

4.3 PROCEDURE RELATED COMPLEXITIES

Present scientific literature on the FED of MR&R challenges revealed the importance of the composition, scope and sequence of the configuration procedure. While analyzing the cases, the MR&R challenges seemed to face additional procedure-related challenges in terms of coordination and agility of the procedure. As theoretical background on these aspects is lacking, this will be added to the introduction of the complexities, before explicating the presence in the observed cases. Altogether, these procedure related complexities and context related complexities shape the playing field public authorities are facing while trying to deal with their set of soon-to-be outdated assets.

4.3.1 Composition

As discussed in subsection 2.4.2, does the composition of the FED procedure relate to the purpose of the project. The FED procedure can be broadly composed of definition, assessment, evaluation and formal decision-making steps. The composition focuses on the subject of the decision (i.e. 'what' is decided) during the process [Ketchen et al., 1996]. However, the purpose of decision-making may differ over time, as the content of the problem which needs to be solved also changes over time [de Bruijn and ten Heuvelhof, 2008]. Assuring the correspondence of purpose and content therefore demands a critical review of the composition of the decision-making procedure, what content is left in and what is left out?

Example 1 - Consciously including or excluding elements in decision making (12)

The importance of having a suitable composition of the context during the FED was also observed in the several cases. For example, PBK has the purpose to reduce the deferred maintenance and additionally tackle the MR&R challenge while trying to mitigate the negative impacts to all stakeholders, whereas PMO focuses on the low-complexity MR&R activities all over the Province [AI3, personal communication, November 18, 2019], [NH1, personal communication, November 25, 2019]. As a consequence of these differences, the FED of the PMO does not consist of extensive condition assessments and categorization of all individual assets, like in the PBK. Decisions whether to incorporate certain elements in the FED of MR&R projects is therefore dependent on the intended outcome of the procedure [RI2, personal communication, November 22, 2019].

Example 2 - Using a stage-gate system (13)

Decision-making on the continuation of the MR&R development to a next phase based on present requirements can be done by the earlier mentioned use of a stage-gate system [Cooper, 1990]. Use of such a stage-gate approach is also traced back in the VenR procedure, as shown in figure A.3. Within the FED procedure, two formal decision-making moments (e.g. gates) are included. First gate checks whether an asset meets the requirements to be included in a new Tranche. If assets meet the exit criteria, they are excluded from the consecutive FED steps. Second decision-making gate evaluates the chosen configuration options. Including these formal decision-making gates creates the opportunity to have a critical view on the rationale to pursue a development to the next phase in a project [RI3, personal communication, December 10, 2019]. However, in-line with the discussed complexity related to the principal-agent problem in subsection 4.3.1, the effect of these formal decision-making gates may be sub-optimal as information asymmetry exists. To reduce the chance of sub-optimal decisions, [Tams, 2010] proposed to not impose high informational requirements in the gates. Reducing the need of

agent-specific (tacit) information in the gates reduces the chance to make sub-optimal decisions due to absence of relevant information at the principal. Together with the previous example, which mentions the possibility to exclude the information required during the FED, the use of a stage-gate system can lead to improved decision-making outcomes and lower necessary effort to find fit-for-purpose configurations. On the contrary, deliberate decisions regrading the assessment criteria need to be made, as the added value of these gate evaluations are dependent on this.

4.3.2 Scope

Determination of the 'optimal' scope in the early stages of a projects is complicated, while a project is subject to sufficient levels of uncertainty [Priemus, 2010]. Narrowing down the scope of the decision-making may improve the speed of decision-making [Salet et al., 2013]. However, achievement of comprehensive outcomes of the decision-making procedure may require a conscious increase of the scope and related complexity [Westerveld and Hertogh, 2010]. For example, infrastructure projects cause serious environmental nuisances during to the execution of construction works [Karydas and Gifun, 2006]. These negative effects are also known as the earlier mentioned social costs, which are related to the effects on health, safety and environment, pollution, traffic flows and economical activities in the area [Çelik et al., 2017]. Through the bundling of different projects into one, the impact on the surrounding environment and joint costs can be reduced on the long term [Westerveld and Hertogh, 2010]. Attention must be paid to making the scope too large. If the decision-making procedure gets too complex, time may be wasted on irrelevant issues [de Bruijn and Dicke, 2006].

Example 1 - Increased scope leads to more interrelations (14)

Reflection of the analyzed cases shows multiple issues regarding a determination of the appropriate scope of the FED procedure. All cases started their FED from a organization wide perspective, concerning all of their assets. VenR narrowed its scope down after a first assessment of the conditions of these assets into a certain Tranche [RI1, personal communication, September 23, 2019]. Integrally for this entire Tranche, intakes are performed. These intakes are standardized to provide an overview of the conditions and related MR&R demand of all assets in the Tranche. Subsequently, all (elements of) assets within this Tranche go though an individual evaluation of sufficient design alternatives. This results in a preferred design alternative for one certain asset within the entire Tranche of 40 projects. The benefit of executing the standardized intakes for an entire Tranche without seeking clustering opportunities within this portfolio is however questionable [RI2, personal communication, November 22, 2019].

Within the PBK, all condition assessments of the assets are continuously done within the scope of the entire PBK on an individual asset base. While deciding upon a project configuration, the Municipality actually takes the presence of other MR&R-needy assets into account. While the urgency of MR&R interventions is relatively high as there is a significant amount of assets in a bad condition, simultaneous execution of MR&R works is a must instead of an opportunity. However, by framing the consequences of MR&R interventions the Municipality aims to reduce the negative consequences on the long term [AI3, personal communication, November 18, 2019]. This also encounters the execution of MR&R interventions on bridges and quay walls which are not entirely at the end of their technical life span. By expanding the scope of the configuration considerations, the Municipality aims to upgrade the state of all assets in the city in order to keep the nuisance and related inconvenience minimal on the long run. Interviews with AI2 and AI3 revealed the complexity of this procedure, as the amount and proximity of the assets is high together with an overall bad condition of the assets. Numerous complex trade-offs between resources and requirements have to be made, which sometimes leads to sub-optimal decisions. However, if the execution of MR&R works would be done from an individual asset perspective, the consequences would be unclear and potentially lead to even worse outcomes [AI2, personal communication, November 18, 2019],[AI3, personal communication, November 18, 2019].

All in all, the analysis showed that the FED procedure and related decisions are made on an asset level, portfolio level or organizational overarching level. Volden [2018] divides an organization in operational, tactical and strategic levels, reflecting the perspective of the decisions which are made. Given the purpose of the step in the FED procedure, deliberate considerations have to be made given

the scope in which this step is executed or on which level the decisions made. As observed in VenR, aligning the situation with the desired level of decision making can be critical in finding potential configuration options [RI1, personal communication, September 23, 2019].

4.3.3 Sequence

Positioning of the separate steps of the FED determined to have significant consequences for final decisions regarding the configuration of MR&R projects. A balance needs to be found between sufficient space to make comprehensive decisions and keep speed in the process [De Bruijn et al., 2010; Alomar et al., 2016].

Example 1 - Premature convergence leading to path dependency (15)

Research by [Westerveld and Hertogh, 2010] mentioned that premature convergence (e.g. choosing a solution early in the process) kills of the other alternatives which are present at that time. While for example, the FED procedure of VenR was designed for an individual asset-by-asset approach, options to seek configuration opportunities with other assets in the later FED steps were minimized. Even though the intakes which assessed the conditions of all assets in Tranche 4 were conducted during the beginning of step 4 (as seen in figure A.3, the earlier made decision to go through the FED procedure for all (elements of the) assets individually made the procedure path dependent [RI3, personal communication, December 10, 2019] [Joosse and Teisman, 2020]. Absence of premature convergence opened opportunities for KARGO and PMO to be configured as a program. This resulted in the opportunity for KARGO en PMO to make significant efficiency improvements through reducing organizational efforts and providing conditions for learning-by-doing [RI2, personal communication, November 22, 2019].

Example 2 - Options to postpone crucial activities (16)

Within the FED of VenR and PBK, the condition assessment of the assets takes place before the design alternatives are developed and evaluated. Of these design alternatives, one is ultimately chosen and further developed as a MR&R project. Nonetheless, the configuration of MR&R projects is also possible without evaluating design alternatives [RI2, personal communication, November 22, 2019]. KARGO left this responsibility with the bidding contractors as part of their proposal, whereas the GBC within the PMO of the Province North-Holland were rewarded on qualitative criteria instead of extensive MR&R considerations [NH1, personal communication, November 25, 2019]. One of the main lessons learned of KARGO was that the exact scope of the MR&R works can be determined once a contractor starts conducting really detailed condition assessments [RI2, personal communication, November 22, 2019]. In the light of the VenR intakes, gathering asset information in detail up front was determined to be costly and time consuming during this stage of the FED procedure. However, absence of data confirming the exact state and related technical end of an asset's lifetime causes a risk with a related uncertainty in terms of decision making on the design alternatives and configuration options. To fill the gap of lacking data on asset condition, inspections for asset valuation are necessary [Glendinning and Hall, 2011; Schraven et al., 2011]. Therefore, sequence in the FED procedure of these inspections which assess the asset conditions differs per case and is related to the ability to consider design alternatives and the input for configuration trade-offs.

4.3.4 Coordination

An element which lacks significant attention in scientific literature is the coordination of the FED phases of MR&R projects. Next to the projects and programs which are configured at the end of the FED procedure, the FED procedure itself is also coordinated in a certain manner. To put the different procedure coordination options in perspective, project-focused design of the FED means that all steps (as shown in in figures 2.10, 2.11, A.3 and A.9) are independently traversed for one single project. Whereas the program-focused designs carries out all separate steps and makes the related decisions synchronous with a multitude of assets to create intended benefits. However, alignment of decision-making authority with a coordination method is not a matter of course. To add theoretical background

on the coordination challenges of MR&R projects, the following explanation is added:

Project teams (agents) naturally have other (intangible) information than people within higher management functions (principals) [Cantarelli et al., 2010]. However, the decision-making authority on projects is often placed at the latter group. To know what is needed in a renewal and replacement challenge, top-down and bottom-up intra-organizational communication is key [Mom et al., 2007]. On one side, communication should support knowledge inflows towards top-management to create an improved insight in the exploitation and exploration activities at executive levels of the organization. On the other side causes the delegation of tasks towards the executive levels of an organization a challenge due to possible internal conflicts of interest. Altogether, this can be delegated to the so-called principal-agent problem [Laffont and Martimort, 2015]. Winch [2002] developed a Johari window (originally created by [Luft and Ingham, 1955]) to visualize the information challenges in construction projects. As can be seen in figure 4.4, feedback and disclosure are necessary to increase the available body of knowledge among both the principal and agent.

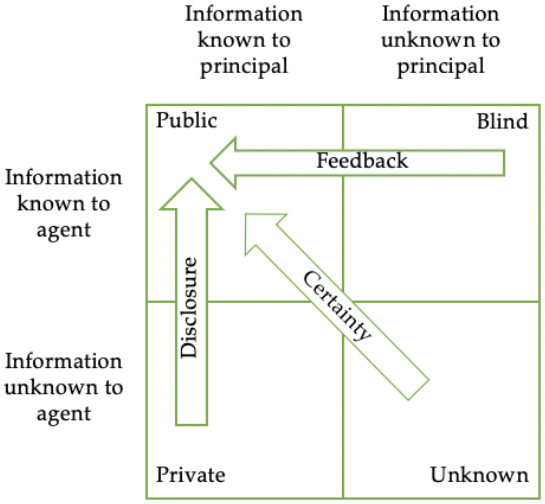


Figure 4.4: Construction industry specified Johari Window regarding information availability and decision making [Winch, 2002]

Trade-offs regarding the inclusion of executive divisions in the decision-making procedure on projects is balancing between improvement of knowledge sharing and fuzziness of decision-making processes [Bellman and Zadeh, 1970]. Large infrastructure projects are commonly known for involvement of too many parties which results in sluggish decision making [De Bruijn et al., 2010]. If everyone gets involved in decision-making, the procedure will get too complex and it will hardly come to explicit decisions. On the contrary, if agents are not included decisions will lack substantial (tacit) knowledge. The level of agent participation in relation to the fuzziness and sluggishness of decision-making can be aligned with the coordination method. The organizations in the analyzed cases dealt with this coordination-related complexity in several ways, which will be explained separately.

Example 1 - Creation of a program (17)

The Municipality of Amsterdam developed an individual program, called "Programma Bruggen en Kademuren", with an own board, financing structure and adjusted working processes. As shown in the organizational structure in figure A.8, the Program Board is in direct contact with the executive divisions which keeps the distance between principal and agent as small as possible. All aspects which are directly relevant for the decision-making on the MR&R related topics are bundled inside the PBK [AI2, personal communication, November 18, 2019]. However, in contrast to the 850 bridges and 200 kilometers of quay wall which are included in the PBK, the KARGO program consisted of just 8 eight bridges. Within this program, the coordination of all MR&R activities was coordinated by one management team which had the ability to oversee the entire program. A significant difference between the span of control and related manageability effort between the coordination of PBK and KARGO is

evident. Therefore, creation of a program and related complexity of coordination is strongly related to the size of the program [RI2, personal communication, November 22, 2019].

Example 2 - Including VenR in the regular work flow (18)

In contrast to the Municipality of Amsterdam, Rijkswaterstaat deliberately decided to not develop a separate program, but incorporate the VenR challenge and related activities inside the existing organizational structure (as visualized in figure A.2. Interviewee RI3 explained that Rijkswaterstaat sees their MR&R challenge as an integral part of their organization with close interfaces to the existing organizational divisions. Development of a new MR&R division would lead to a new 'island' which will operate relatively independently of the rest of the organization. To prevent this, Rijkswaterstaat is trying to embed the MR&R projects into the regular stream of projects within the existing divisions [RI3, personal communication, December 10, 2019]. However, this places decision-making authority on the MR&R projects also within the existing centralized structure, without a separate MR&R or VenR division or director with any mandate. Chances for asset transcending project configurations are missed so far, which may be attributed to the presence of information asymmetry due to the earlier discussed principal-agent problem [RI1, personal communication, September 23, 2019].

4.3.5 Adaptivity

The second procedure-related complexity which was underexposed in the theoretical background of MR&R project configuration was the presence and importance of adaptivity. Outcomes of decisions may differ from the initial intentions due to uncertainty influencing the predictability of project development at the time of a made decision [Mitleton-Kelly, 2003; Sperry and Jetter, 2009; Edkins et al., 2013]. However, the level of uncertainty regarding the outcome of made decisions decreases as a project continues, which provides the opportunity to evaluate and revise the made decisions [Kim and Wilemon, 2002; Sanderson, 2012]. Revising made decisions due to the presence of new insights is related to the adaptiveness of the decision-making procedure [Rijke et al., 2014; Zandvoort et al., 2018]. Including adaptivity in the analysed MR&R cases also observed in some of the cases, which will be discussed in more detail in the examples.

Example 1 - Introducing GBC in a phased manner (19)

After the decision was made to outsource the determined low-complexity MR&R works in a regional matter, the actors involved in the PMO had to determine a way to express their needs in a contract. The contracts had a duration of ten years in which the Province wanted to be relieved of all executive and coordinating tasks. However, a major challenge emerged on how to express the Province's needs in a context of changing circumstances and related uncertainty [Demirel et al., 2017]. Since experience with these kinds of contracts was lacking, the Province decided to introduce the GBC in a phased manner. By doing so, the idea was to work on an trial-and-error basis while learning from past performance [NH1, personal communication, November 25, 2019]. Input from lessons learned of older GBC were used as input for new GBC. Program manager NH1 mentioned that working in an adaptive manner resulted in a situation where the Province can respond in an effective manner to unforeseen circumstances. In advance it is hard to know exactly how to formulate a contract which covers all of the activities a Province wants to outsource in a convenient matter. Rolling out the GBC in a phased matter and adapting the context based on new insights therefore resulted in opportunities to tighten the gap between expectations and outcomes. The older contracts which did not consist of these new insights were adjusted 'on the go', which led to some adjustments in the expenses as these aspects were not part of the original contract [NH1, personal communication, November 25, 2019].

Example 2 - Revising the FED process for a new Tranche. (20)

The FED of VenR follows a process, which is discussed in subsection A.1.2. Compared to Tranche 1 until Tranche 3, the currently ongoing Tranche 4 changed this procedure, by introducing the execution of Tranche-wide intakes of all assets which are part of Tranche 4. After the FED of the first three Tranches were completed, different involved persons acknowledged the missed opportunities of having such a

large set of soon-to-be outdated assets [RI3, personal communication, December 10, 2019] . By introducing a Tranche-wide uniform intake procedure, the intention is to get a comprehensive overview of all assets which are part of this Tranche, instead of simply going through the FED procedure for one asset. The added value of having an overview of the assets in a Tranche, is to seek opportunities to merge assets which potentially could lead to certain benefits. As mentioned by the Head of Procurement Department RI3: *"Having similarities among the assets in a Tranche and actually merging these assets into a project or program can reduce the need to develop individual teams for each asset, prepare and go trough the tender procedure only once for a multitude of assets and manage impacts of traffic nuisance in a better way." Creating the opportunity to evaluate and revise (parts of the) FED procedure, therefore creates opportunities to perform more and more in a fit-for-purpose manner [RI3, personal communication, December 10, 2019].*

On the other side, following the same standardized procedure over and over again creates certainty in the procedure and outcome [Nicholas and Steyn, 2012]. Changing the FED procedure decreases the opportunity to creative repetitive advantages since the adjustment demands a new way of working for the involved teams. In VenR Tranche 4, this resulted in a situation where the intakes were carried out by a special independent team, whereas the project teams responsible for the asset in the Tranche continued to follow the old procedure. This resulted in a situation where the outcomes of the intakes were of limited value, as teams already moved on along the procedure and were investigating potential design alternatives by themselves. The advantage of integral intakes and the following opportunities of merging these projects are therefore missed [RI2, personal communication, November 22, 2019]. Changing the FED procedure therefore does not guarantee the potential benefits, as this is highly dependent on the compliance of the involved persons at an actor level.

4.4 VALIDITY OF THE ANALYSIS

As the cross-case analysis consist of four cases, the results of the comparison will not be fully generalizable for the all MR&R projects in the transportation infrastructure sector. The overview of present complexities in table 4.1 is therefore non-exhaustive. In other MR&R cases, additional complexities may be present or present complexities may be absent. Expanding the cross-case analysis with more cases would however improve the validity of the results, as the sample would become closer to a representative reflection of the reality. However, as the case comparison consist of four cases of three different public authorities with completely different project characteristics, the analysis intends to provide a representative overview of the actual complexities related to the decision-making on project configuration during the FED of MR&R projects. The difference among the cases is therefore seen as a strength to improve the opportunity to create a decision-making framework which is generalizable for all MR&R challenges of public authorities in the transportation infrastructure domain.

4.5 CONCLUSION

Based on the theoretical analysis in the previous chapter, the context of the comparative case analysis was provided. These insights provided a first glimp of the dynamics which go on during the FED of MR&R projects and shed light on the 'black box' as shown in figure 1.1. By analysing four MR&R cases both individually and jointly on context related and procedure related complexities, the following sub-question is answered:

***Sub-question 2** - "What are the main challenges related to the configuration of MR&R projects in practice?"*

In order to find these challenges, the four cases were mirrored to the identified complexities in chapter 2 to figure out how these aspects actually lead to complexities during the FED. Besides, the case analysis also resulted in the acknowledgement of additional aspects which had not been identified during the secondary literature review. Given the observed importance of the organizational strategy, the coordination and agility on the FED procedure, it was decided to subsequently include these aspects in the analysis. This resulted in the overview of complexities as shown in table 4.1. The distinction between context related complexities and procedure related complexities is preserved to highlight the differ-

	Complexities	No.	Description
Context	Requirements	1	Influence of organizational strategy
		2	Amount of requirements
		3	Conflicting requirements
	Asset conditions	4	Detail of condition assessments
		5	Need of certain expertise
	Resource allocation	6	Composition of teams
		7	Financial flexibility
	Design alternatives	8	Varying impact of design alternatives
	Configuration methods	9	Diversity of configuration grounds
		10	Variety of configuration options
		11	Necessary effort to find configurations
Procedure	Composition	12	Consciously including or excluding elements
		13	Using a stage-gate system
	Scope	14	Increased scope leads to more interrelations
	Sequence	15	Premature convergence leading to path dependency
		16	Options to postpone crucial activities
	Coordination	17	Creation of a program
		18	Including VenR in the regular workflow
	Adaptivity	19	Introducing GBC in a phased manner
		20	Revising the FED process for a new Tranche

Table 4.1: Overview of the present complexities during the FED of MR&R projects

ences between the background of the complexities. To visualize the identified interactions between the context related complexities, figure 4.3 was developed. However, the way these interactions take place during the FED is dependent on the elements which influence the procedure. Altogether, the discussed complexities shape the environment which influence the configuration procedure of assets during the FED. Based on these insights and the analyzed FED processes, a decision-making framework will be built to deal with these complexities. Using the observed complexities of this chapter is intended to create a comprehensive overview of potential ways to deal with the stated challenges, which will be the basis of the framework.

A last note is related to the validity of the analysis. The analyzed cases had multiple difference related to the size, purpose and context of the MR&R challenges. For example, the PMO case was focused on relatively small and easy MR&R interventions compared to the large steel arched bridges of the KARGO case. Nevertheless, the purpose of this research is not to create a decision-making framework which is perfectly fit for one specific situation, but to create a procedure and method to approach MR&R challenges within the transportation infrastructure industry in general.

5 FRAMEWORK DEVELOPMENT

As identified in the previous section, public bodies responsible for the transportation infrastructure have to manage their arsenal of assets with a bunch of related challenges. These challenges are present on various institutional levels and touch on different characteristics related to the renewal and replacement challenges. Within a featured challenge, often multiple opportunities arise to deal with the present complexities, which leads to dilemmas for the decision makers. Therefore, this section will provide an overview of the dilemmas which public bodies face while setting up their FED of MR&R projects. The decision to approach these challenges as dilemmas is made to indicate how public organizations may deal with their MR&R challenge. By explaining the potential decisions public organizations can make while facing such a challenge, this chapter aims to provide an overview of these decisions and the related considerations.

Dealing with these dilemmas is both necessary and complex, as they have significant impact on the FED process which leads to MR&R project configurations. In the end, it are the configurations which determine how a project or program may create value in the consecutive project phases. While the two or more alternatives inside a dilemma both have pros and cons, deliberate trade-offs have to be made. Based on the insights of the case comparison in chapter 4, grounds for these decisions are indicated. Thereby, the interrelatedness of the dilemmas plays an important role, as one decision may affect the consequences of other decisions. Altogether, these identified trade-offs will function as the body of the to be developed decision-making framework. This framework will show the opportunities public organizations have in dealing with the challenge regarding the increasing amount of soon-to-be outdated assets. By visualizing the trade-offs related to the configuration of MR&R projects, it is intended to create an overview of the decision-making opportunities.

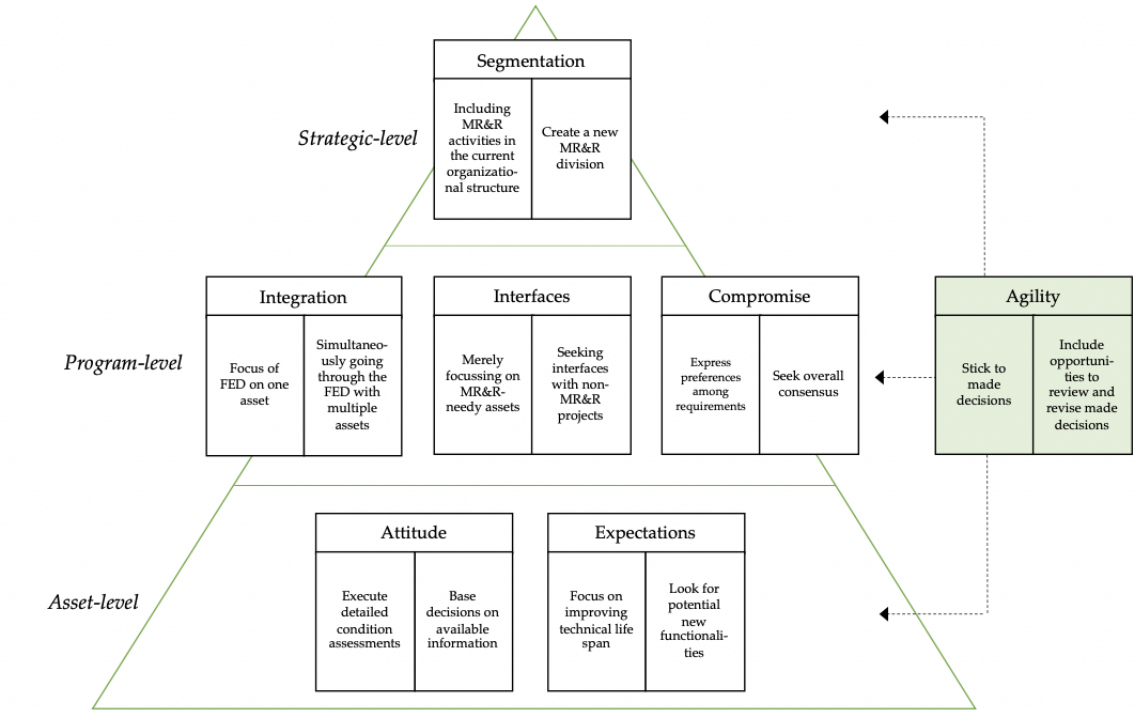


Figure 5.1: Overview of the identified dilemmas

The identified dilemmas which public organizations are dealing with during the FED of MR&R challenges are related to: segmentation, integration, interfaces, compromise, expectations, attitude and agility. First, the dilemmas will be discussed separately by introducing and discussing the trade-offs. To emphasize the links of the dilemma with the identified complexities, these will be listed in every section. The order of the explanations is determined on the earlier discussed differences of institutional levels. By starting with the highest level (e.g. the organizational-wide strategic perspective), a divergence to the following program and asset level dilemmas is made. The agility dilemma is not attributed to a certain level, as this trade-off applies in every institutional layer. An overview of the division of dilemmas is shown in figure 5.1. This overview will function as a basis for the decision-making framework. This decision-making framework will be developed in a manner that public organizations can adjust their unique characteristics to a final process design. Based on these unique conditions, deliberate decision-making can take place which jointly shapes the design of the FED process. The chapter ends with a conclusion which answers sub-question 3:*"How could a decision-making framework be designed to deal with MR&R projects in a fit-for-purpose manner during the FED?"*

5.1 SEGMENTATION

With the inevitable rise of soon-to-be outdated assets (as shown in figure 2.1), public organizations will be dealing with a new kind of projects related to MR&R interventions [Nicolai et al., 2016]. FED of MR&R projects significantly differs from other (e.g. greenfield and maintenance) projects [Ng et al., 2009; Koppinen and Rosqvist, 2010]. MR&R-needy assets have unique challenges due to their current physical condition and role in the present infrastructure network, which creates an uncommon set of necessary deliberations during the FED [Karydas and Gifun, 2006]. As observed in the cases, there is no uniform way to accommodate this kind of projects. For example, the Municipality of Amsterdam decided to develop a totally new division (shaped as a program) within the present organization, next to existing divisions which deal with new development plans and regular maintenance of the assets. On the other side, Rijkswaterstaat deliberately decided to not create a new division, as they emphasize the interfaces with the existing divisions and the benefits of integrating MR&R projects into the current flow of projects. The presence of multiple options to coordinate the current and future stream of MR&R projects therefore results in a dilemma on a strategic level which is called: the segmentation dilemma. Segmentation in this sense refers to the trade-off whether to coordinate MR&R projects within the current organizational structure and line of project development or to create a new division to focus primary on the development of MR&R projects.

5.1.1 The dilemma: Including MR&R in the organization versus Creating a new division

The first option is to keep the organizational structure as it was and to embed the flow of MR&R projects into the existing divisions. These organizational departments have their own procedures related to the development of projects. MR&R projects will be added to their current portfolio of projects and part of their FED. The other option is to create a new division which has a primary focus on the development of MR&R projects. All soon-to-be outdated assets become the responsibility of the new division. Critical question which needs to be answered is: Based on which grounds could a public organization decide to choose for a certain approach? Related complexities as identified in chapter 4 to this trade-off are:

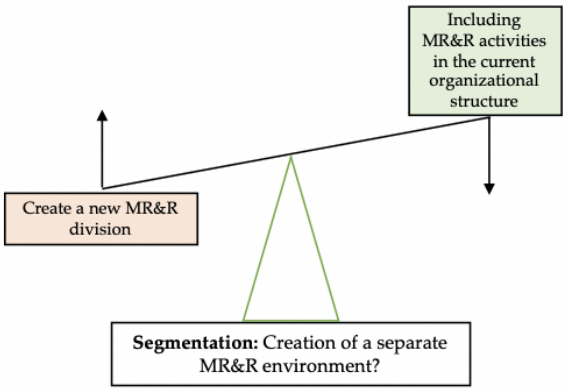


Figure 5.2: The segmentation dilemma

- (1) Requirements - Influence of organizational strategy
- (6) Resource allocation - Composition of teams

- (14) Scope - Increased scope leads to more interrelations
- (17) Coordination - Creation of a program in Amsterdam
- (18) Coordination - Including VenR in the regular workflow

5.1.2 Relevant considerations

In essence, the segmentation dilemma is related to the decision to carry out the MR&R activities in an individual and independent manner or in an enclosed environment together with other 'MR&R-needy' assets. Including the MR&R projects into the current organizations has certain advantages, as the need to set up a new organizational division is absent. Known procedures can be followed and by accommodating these MR&R projects in existing divisions, standardization benefits can be exploited [Sydow et al., 2004]).

By enclosing the environment, interfaces between MR&R projects are easier to be found [AI3, personal communication, November 18, 2019]. Despite the significant organizational effort to create a new organizational division related to MR&R projects, this creates a set of opportunities over and above the ability of a single project [Heising, 2012]. Programs, as separate divisions within an organization, are known for their ability to create advantages like the realisation of strategic benefits and integrated coordination of a set of projects[Ferns, 1991; Pellegrinelli, 1997; Partington et al., 2005]. Having a centralized environment, creates the ability to become a 'learning organization' [Thiry, 2002]. Gained knowledge returns to the same environment which improves the opportunity to use these findings in the development of new projects [RI2, personal communication, November 22, 2019]. Having this opportunity also improves the ability to adjust to changes in a vibrant environment like the MR&R context [Kim and Wilemon, 2002]. By shortening the connections between the decision-making authorities and the employees within the separate MR&R division, intra-organizational communication is easier which decreases the potential knowledge gap between the principal and agent [Mom et al., 2007; Winch, 2002]. Thereby, opportunities for tuning the MR&R demands to the present abilities of the (specialized MR&R) contractors also increases if these can be aligned during the FED of programs [Liu et al., 2019]. All in all, the potential benefits of creating an enclosed MR&R environment are diverse and promising.

However, creation of a new MR&R division within an organization does not eminently leads to the earlier described benefits. The composition of the program needs to be deliberately adjusted to the purpose of the program. Referring back to the earlier discussed options of portfolio, goal-oriented and heartbeat programs as discussed in section 2.5.1, an organization should consider the presence of these options in contrast to their own challenge [Pellegrinelli, 1997]. The success of creating a new MR&R department is logically also dependent on the consequent management of the division [Lycett et al., 2004]. Acknowledgment of the existing span of control is thereby an important aspect, as surpassing this can lead to manageability issues which may affect the functioning of the division [Leijten, 2017]. For example, both KARGO and PBK are designed as a program. However, KARGO consisted of eight bridges, while PBK consists of 850 bridges and 200 kilometer of quay walls. As the magnitude of the programs differs to a great extent, success of segmenting MR&R activities in a program is also highly dependent on the size. It is a matter of course that realizing the previously stated benefits and managing the entire FED process becomes harder with an increase scope of the segmented MR&R division.

The decision to set up a specified MR&R division within the organization is therefore highly related to the intended purpose and abilities of the organization. The trade-off has to be made whether an organization wants to do projects well (within time, on budget and of a certain quality) or also wants to focus on objectives on a higher institutional (read: strategic) level. Given the unique characteristics and relative novelty of MR&R projects, organizations may benefit from an integrated approach which creates a basis to share knowledge over projects. Nevertheless, integration of MR&R activities with other existing organizational divisions also creates the ability to take advantage of existing networks and procedures. When strategic ambitions related to MR&R projects and organizational abilities to develop a new division are present, choosing for a program-based approach could be beneficial. When

an organization is lacking such tactical demands or sufficient means to set up a new MR&R department, due to the limited presence or expected challenge of related projects, the existing way of project development could be maintained. Thereby, the size of the segmented division also influences the ability to realize the benefits of enclosing the MR&R projects. It is not necessary to develop an entire new department to enclose a set of projects, if the size of the enclosed assets in manageable within a current division. This can be seen as a hybrid form, which is in between the two discussed options. The final decision whether and how to segmentate MR&R-needy assets should consider that: the larger the span of control, the larger the amount of considerations and interrelation, the more effort has to be put in managing the ensemble [Leijten, 2017].

5.2 INTEGRATION

Traditionally, an asset manager is in charge of an asset's functionality and safety [Klerk and Den, 2016]. Since MR&R challenges seemed to be present all around the organization, opportunities to look beyond the borders of a single asset (as discussed in section 2.2) emerged. However, to create a situation where these links between MR&R-needy assets can be found, the opportunity needs to be created [RI2, personal communication, November 22, 2019]. A potential opportunity to create this, is through executing the FED steps, as described by Šelih et al. [2008]; Nielsen et al. [2016] in subsection 2.4.3 simultaneously for a multitude of assets. However, the expanded amount of considerations and interrelations leads to significant increase in the complexity of the decision-making process [AI3, personal communication, November 18, 2019] [San Cristóbal et al., 2018]. The opportunities to go through the FED and make decisions on the configuration with an assembly of assets, in contrast to the potential increase in the complexity of the decision-making procedure creates the so-called: integration dilemma. Integration in this sense, refers to the execution of the FED procedure for every asset in isolation of the other assets or collectively with multiple assets.

5.2.1 The dilemma: Scope of FED on one asset versus a larger environment

The first options an organization has is to keep the scope of the FED on one asset. When this option is chosen, the assets go through the different steps of condition assessments, determination of potential design alternatives and the final configuration individually. The other option is to expand the scope of the FED procedure by going through this with a multitude of assets at the same time. Expanding the perspective of the FED procedure increases the opportunity to find fit-for-purpose solutions as the configurations may consist of a combination of assets. Related complexities as identified in chapter 4 to this trade-off are:

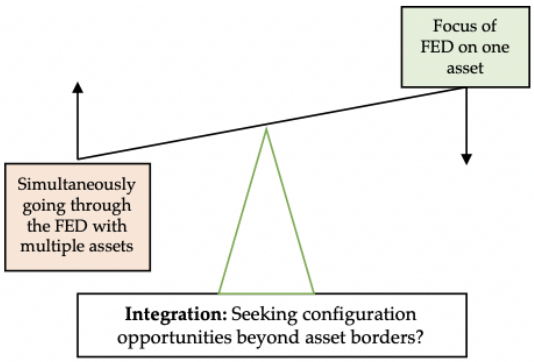


Figure 5.3: The integration dilemma

- (6) Resource allocation - Composition of teams
- (10) Configuration methods - Variety of configuration options
- (11) Configuration methods - Necessary effort to find configurations
- (12) Composition - Consciously including or excluding elements
- (14) Scope - Increased scope leads to more interrelations
- (16) Sequence - Options to postpone crucial activities

5.2.2 Relevant considerations

Public organizations within the transportation infrastructure domain are often responsible for a bulk of heterogeneous asset which will all reach the end of their technical life span sometime. Once an asset gets marked as MR&R-needy, the organizational division in charge can decide to start the FED for this single asset. Choosing to execute the FED for all assets individually keeps the procedure straightforward and relatively easy to oversee for the persons involved. However, if every asset goes through the FED individually, for every asset there needs a new team to be set up which is responsible for the related activities. With the upcoming MR&R challenge as predicted by Nicolai et al. [2016], the need of human resources will increase in the same proportions if this one-asset-one-project method is used [RI1, personal communication, September 23, 2019].

As observed in the cases, organizations are responsible for a great amount and diversity of assets. Among these assets, also similarities exists. For example, similarities can be found in the kind of assets (e.g. bridges, tunnels, etc.), the location, used materials, or related complexity of the to-be executed MR&R interventions [Burns et al., 1999]. Presence of such similarities may create opportunities to develop projects jointly and create integrated benefits which would not be achieved if the FED would be executed individually [NH1, personal communication, November 25, 2019]. For example, if Rijkswaterstaat has five noise barriers along various highways all across the Netherlands which need to be replaced, a bundled approach would possibly be sufficient to prepare and execute the project instead of five. Bundling 8 bridges into one program with one team as in the KARGO case, also led to significant benefits related to integrated procurement, risk management, environmental management and learning by doing [RI2, personal communication, November 22, 2019]. Improved risk management was possible due to information sharing, learning, knowledge and competence creation due to the content of the program [Perminova et al., 2008]. Uncertainties seem to decline as reliable data on previous projects becomes available throughout the development of a program, which create the opportunity of learning from experience [Atkinson et al., 2006]. Thereby, commissioning five steel bridges to replace the current bridges from one contractor also provides the ability to get quantity discounts [Nafi and Kleiner, 2010]. Benefits to other requirements like nuisance reductions, managing of traffic flows and providing room to develop innovations and include sustainability aspects are more likely also found as a consequence of the integration of multiple assets in the FED phase [RI2, personal communication, November 22, 2019].

Increasing the scope of the FED and thereby creating more alternatives regarding the configuration of MR&R projects or programs creates both opportunities and threats. Important attention should be paid to the amount and kind of assets which are involved simultaneously. If the amount to-be considered of assets gets too large, manageability issues may arise due to the increased span of control [Leijten, 2017]. To prevent this from happening, organizations may put effort in the deliberated gathering of assets during the FED which have certain similarities. Based on these similarities, potential benefits may be achieved regarding the development of the project or program.

5.3 INTERFACES

Since MR&R projects are assumed to occupy an increased share of the entire portfolio of projects within public organizations, the question raises whether to seek interfaces between the different projects. Traditionally, greenfield, brownfield and maintenance projects are subdivided in separate departments and potentially even divided in regional sub-divisions within one organisation [Seaden and Manseau, 2001; Rashedi and Hegazy, 2015], like for example Rijkswaterstaat and the Municipality of Amsterdam. However, interfaces and interrelations between these

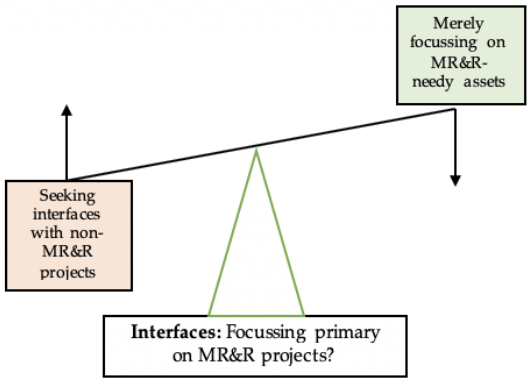


Figure 5.4: The interface dilemma

projects may apply on, for example: physical, organizational, stakeholder grounds [Azim, 2010; Bosch-Rekveldt et al., 2015]. A clear trend of integrated planning and development of infrastructure projects is visible in both scientific research and practice. Research by [Heeres et al., 2016; Martinsuo and Hoverfält, 2018] pinpoint the integrated approach as a useful method to prevent fragmentation. Integrated planning and development of heterogeneous projects is not to be confused with integrated project delivery, where the focus is on the close collaboration between client and contractor during the development of a project [Lenferink et al., 2013a; Zhang et al., 2018]. The presence of other than MR&R projects which may be developed jointly due to certain interrelations leads to the so-called: interfaces dilemma. Interface in this sense refers to the trade-off whether to seek interfaces with non-MR&R projects or keep the focus merely on MR&R project development.

5.3.1 The dilemma: Merely focusing on MR&R versus Actively seek interfaces with non-MR&R projects

The first option is to carry out the FED for MR&R-needy assets only, in relative isolation of other projects within the organization. The other option is to seek configuration options in harmony with other projects which lack a MR&R component. Interrelations between all projects may exist on various aspects, which could be grounds to fuse the development of initially separate projects. Related complexities as identified in chapter 4 to this trade-off are:

- (10) Configuration methods - Variety of configuration options
- (11) Configuration methods - Necessary effort to find configurations
- (12) Composition - Consciously including or excluding elements
- (16) Sequence - Options to postpone crucial activities
- (17) Coordination - Creation of a program in Amsterdam
- (18) Coordination - Including VenR in the regular workflow

5.3.2 Relevant considerations

Organizations will be facing the necessity to execute MR&R projects, next to their other projects, in a greater extent in the coming decades [Nicolai et al., 2016; Levinson, 2018]. With the increase of MR&R projects the potential interfaces with (to-be) planned greenfield and regular maintenance is also likely to increase. Interviewee RI1 mentioned that interfaces between greenfield projects and renewal or replacement works are very often found during the exploratory phases and executed within the scope of the to-be developed greenfield project [RI1, personal communication, September 23, 2019]. The MR&R activities are often small-scaled works like viaducts or culverts, which do not significantly increase the scope of the initial project and lay directly within the geographical boundaries of the greenfield project. Since the upcoming MR&R challenges of the public organizations in the observed cases also consist of larger and complex civil structures, the question rises whether it is beneficial to search for promising (potentially less evident) interfaces.

On one side, one may argue that MR&R (especially renewal) projects require special kinds of expertise [RI2, personal communication, November 22, 2019] [Thuvander et al., 2012]. Given the uncertainties which complicate the determination of the exact scope and related budget of the to be executed works during the preparatory phases of MR&R works, this may interfere with the necessary levels of certainty greenfield projects require before heading on to the more detailed design and procurement phases [Leiringer, 2006; Lenferink et al., 2013a]. It may therefore not be desirable to merge both kind of projects into one.

On the other side, Osman [2016] describes four potential benefits of integrated coordination of infrastructure project: Minimizing community disruption, optimizing overall objectives of infrastructure management (LCC, risk exposure etc.), more efficient tendering and ability to merge construction works in larger projects which may attract more contractors. Especially the last argument is questionable for some public organizations, as Rijkswaterstaat for examples faces issues in attracting rather

small instead of large contractors [Rijkswaterstaat, 2014]. Therefore, the discussed benefits are strongly related to the conditions of the potentially merged projects.

Despite to the discussed pros and cons of seeking interfaces, the main question of this dilemma regrading the design of the FED is whether public organizations should actively seek interfaces with other projects. The ability to find these interfaces is strongly related to the other dilemmas, like segmentation and expectation, which shape the environment of the FED, as they indicate the organizational proximity [1] between MR&R and non-MR&R projects. If the necessary effort to find potential interfaces is relatively low and the benefits of merging MR&R projects are high, there is little reason to not seek these interfaces. However, if the effort to seek these is significant and the MR&R projects demands relatively a quick intervention, then it is possibly not worth it [AI1, personal communication, November 1, 2019].

5.4 COMPROMISE

One aspect which was observed in all cases but often lacks explicit emphasis of public authorities in practice, is the trade-off whether to seek overall consensus or decide to express preferences on present requirements during FED decision-making. Related projects often start with the simple idea of renewing or replacing an asset, but can become very complex as they have to deal with different purposes and interests in an ever changing environment [Salet et al., 2013]. Merging these conditions leads to the following question for the public authority in charge: *"How to cope with the amount of requirements which arise during renewal and replacement projects?* In the light of MR&R projects, which are characterized by ill-structured problems, dynamic conditions, time pressure, multiple stakeholders and technical complexity, decisions are sometimes insufficiently fathomed by the authorities [Chen and Bai, 2019]. Dealing with the presence of divergent interests therefore results in the so-called: compromise dilemma. Compromise in this sense refers to the trade-off whether an public organization tries to seek overall consensus among present requirements or decides to attribute a certain rank to the requirements in charge to ease the decision-making procedure.

5.4.1 The dilemma: Seek overall satisfaction versus Expressing preferences

One option the public organization has is to gather the present requirements of both internal and external stakeholders and try to seek consensus among these requirements. In the end, in Dutch transportation infrastructure projects the public organization is the responsible authority which has the obligation to perform in everyone's interest [Yu et al., 2018]. On the other side, being in this position of authoritative actor also creates the opportunity to guide the configuration procedure. Benefits of a certain configuration may transcend the objectives of individual involved stakeholders and stimulate the realization of public requirements. While being the public authority in charge, certain preferences regarding the configuration can be stressed which are still in line with their authoritative responsibilities. Expressing those preferences should however be explained, as some stakeholders may feel passed as their interest are possibly not served in a certain configuration where preferences among present requirements are attributed. Related complexities as identified in chapter 4 to this trade-off are:

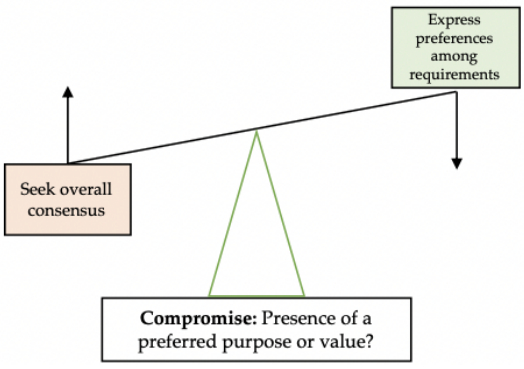


Figure 5.5: The compromise dilemma

- (2) Requirements - Amount of requirements
- (3) Requirements - Conflicting requirements

1 Organizational proximity in this sense refers to the ability of different project teams to find each other due to the presence of an overarching department or directorate

- (8) Design alternatives - Varying impact of design alternatives

5.4.2 Relevant considerations

Dutch decision-making is characterized by the famous 'polder model', which emphasizes the consensus-oriented culture [Wiering and Arts, 2006]. The decision to involve all parties in the decision-making procedure and aim for consensus however results in three major disadvantages: excessive levels of complexity, presence of strategic behaviour and the involvement of 'all' is not an objective criterion [de Bruijn and ten Heuvelhof, 2008]. Even though it is the role of an public organization to serve everyone's interest, a trade-off should be made between the complexity of reaching consensus and the added value of these consensus-seeking outcomes. de Bruijn and Dicke [2006] mentioned that if the decision-making procedure gets to complex, time may be wasted on irrelevant issues. Now time is exactly one of the elements which is critical in MR&R challenges.

One way to tackle these challenges related to complexity of decision-making is through the relatively rigid measure which puts focus on rational decision-making and de-emphasizing political and societal variety [Salet et al., 2013]. Sustainability, accessibility, safety are all examples of (public) requirements which played an important role in the FED of the analyzed cases. Logically, they are are all likely to be salvaged in the configuration and the FED procedure towards this configuration [Liu et al., 2019]. However, the relevance of all of the stated requirements may differ among the MR&R-needy assets of an organization. For example, if a bridge in a remote area is near the end of is technical life span, the consequences to the accessibility of the area are possibly not comparable to the consequences of necessary renewal or replacement of a bridge on one of the busiest highways of the country. Even though accessibility is an important in all cases, the importance and related effort to attribute to this requirement may differ per case. Expressing preferences among present requirements may therefore speed up and ease the decision-making procedure, which is important to deliver value in projects [Welde and Volden, 2018]. However, having the opportunity to make quick decisions is also related to the communication and information sharing among the project teams and decision-making authorities [Pargar et al., 2019].

This dilemma is strongly related to the segmentation, interfaces and integration dilemma, as the opportunity to encounter the importance of certain requirements on an asset-transcending scale creates the opportunity to reconsider the relative importance of certain requirements for an organization per case [Ahola et al., 2017]. If the opportunity to compare assets and related importance of present requirements is absent, varying importance of requirements still may be present [R12, personal communication, November 22, 2019]. However, the opportunity to create asset transcending benefits like economies of scale and integrated safety or accessibility solutions for decision-makers is absent [Sjoerdsma and van Weele, 2015; van Riel et al., 2017].

Deciding to seek consensus among the various viewpoints regarding the configuration of MR&R projects is the rule rather than the exception in the Netherlands. However, in the context of MR&R challenges where decisions regarding the configuration of a multitude of assets have to be made, this may lead to time-consuming and sub-optimal outcomes. Dependent on the conditions and requirements a authority faces, it may decide to attribute certain preferences among the present requirements. Instead of compromising with 'all' involved stakeholders, authoritative power may be used to prevail certain requirements over others, in order to serve the public interest in a fit-for-purpose manner.

5.5 ATTITUDE

Traditionally, (public) organizations use the FED to determine why, which project and how the project is to be developed [Gibson et al., 2006; Edkins et al., 2013]. Success of these projects is however strongly influenced by uncertainties which can not be fully estimated and consist of 'unknown unknowns' [Wang et al., 2017]. This creates a difficult situation, as an organization logically tries to reduce the uncertainty by investing in the accumulation of information [Samset, 2009]. However, time to reduce

present uncertainties during the FED may be scarce as a consequence of the related urgency of action in MR&R projects [Heeres et al., 2016]. One major contributor to uncertainty within MR&R projects are the existing structural dynamics which were developed decades ago. Mechanical behaviour and related deterioration rates of the assets are therefore hard to identify [Casciati and Lagorio, 1996]. The observed cases dealt with this in various ways. For example, KARGO decided to accept the fact that they did not know the exact state of the assets at the time the configuration of the program took place. On the other side, the FED of VenR attributes significant time and effort in the technical condition assessment of the assets [RI2, personal communication, November 22, 2019]. The fact that an organization has to make a decision whether to acquire information to reduce uncertainties before moving from the FED towards the procurement phase, results in the attitude dilemma. Attitude in this context refers to the trade-off whether to (not) accept a certain level of uncertainty is present while configuring MR&R projects.

5.5.1 The dilemma: Execute detailed condition assessments versus Base decisions on available information

While dealing with the present levels of uncertainty during the FED of MR&R projects, the question remains if the organization is willing to accept uncertainty? Uncertainty affects the possibility to predict and secure the design, tasks, time and budget of a project [Atkinson et al., 2006; Koppenjan et al., 2011]. However, is it really necessary and possible for an organization to capture the scope of the project during the FED? As mentioned before and observed in the cases, MR&R projects are subject to different levels of (technical) uncertainty which influences the ability to determine the scope of the to-be-executed project [RI2, personal communication, November 22, 2019]. Apart from the cases which need immediate interventions, the cases showed a vast amount of assets which lacked the urgency of action due to related safety issues. Definition of the exact MR&R interventions during the FED phases is therefore in some situations less necessary, if the organization has the attitude to accept instead of avoid uncertainty. Thereby, scope changes are a major cause of contract changes and related cost overruns in infrastructure projects [Flyvbjerg, 2007; Verweij et al., 2015]. Gathering information to reduce uncertainty and related decision-making to lock the scope of a project during the FED is therefore questionable. Accepting the fact that these uncertainties are simply present during the early phases could be another attitude of the public organization. Related complexities as identified in chapter 4 to this trade-off are:

- (5) Asset conditions - Need of certain expertise
- (7) Resource allocation - Financial flexibility
- (9) Configuration methods - Diversity of configuration grounds
- (11) Configuration methods - Necessary effort to find configuration
- (12) Composition - Consciously including or excluding elements

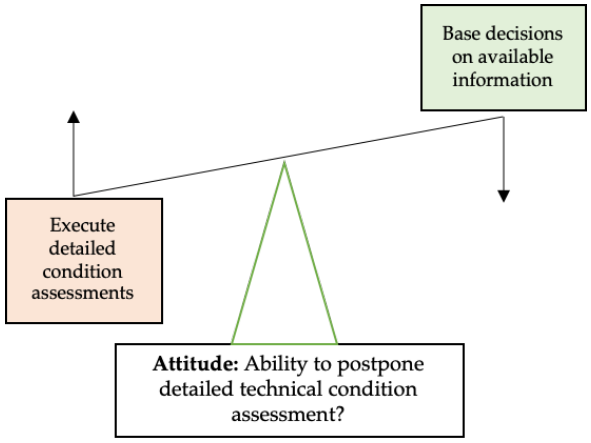


Figure 5.6: The attitude dilemma

5.5.2 Relevant considerations

To start with, the possibility to base decisions on present information is sometimes simply not present. As observed, MR&R challenges may differ in size, complexity and requirements. Where Amsterdam deals with dozens of bridges and quay walls which are in a pitful condition, the room for uncertainty during the configuration is logically smaller compared to the division of low-complexity MR&R activities in the Province of North-Holland. Extensive accumulation of detailed data is simply necessary, as safety is at stake [AI1, personal communication, November 1, 2019].

For cases where the room for manoeuvre is not limited by evident constraints like the case in Amsterdam, the trade-off whether to execute detailed condition assessments is more relevant. As the KARGO

case showed us, expertise is required while getting an improved view on the scope of MR&R interventions [RI2, personal communication, November 22, 2019]. However, the timing of these activities may vary. One option public organizations have, is to devote significant effort to reduce uncertainty related to the to-be-executed MR&R interventions during the FED [Vanier et al., 2000]. During the configuration decisions, public organizations have a relatively clear view on content of the MR&R activities so they can plan the interventions, attribute a budget and set up a project team [Cruz and Marques, 2013; Bosch-Rekveldt et al., 2015].

However, as explicitly mentioned by Interviewee RI3: this level of predictability at the FED phase is an illusion as uncertainty during consecutive project phases can still influence the development of the project in unexpected directions [RI3, personal communication, December 10, 2019]. Samset [2009] states that predictability in itself is neither a necessity nor an objective in decision-making. Instead of finding the most appropriate configuration, the decision-maker will employ available resources and expertise to find a solution for the perceived problem. Samset [2009] defines this as one reasons why projects fail in the long run. While detailed technical condition assessments (as observed in VenR) are time consuming and require external expertise Karydas and Gifun [2006]; Luebbe and Weske [2011], the FED procedure and related configuration of MR&R projects could also focus on other elements. By postponing the effort of detailed condition assessments to the phases where the experienced and skilled contractors are responsible for the detailed design and execution of the MR&R activities, beforehand configuration of the MR&R project can be done on other conditions without time-consuming and expensive private involvement [NH2, personal communication, November 25, 2019].

Deciding to avoid uncertainty will evidently result in extensive investments and time-consuming activities with high levels of private involvement to gather the necessary data. As this may conflict with the availability of present resources and requirements, it may be decided to accept a certain level of uncertainty during the FED decision-making on project configurations. Reducing uncertainty to a level of full predictability regarding project development is thereby simply impossible. Deliberate trade-offs within the organization are therefore to be made, which level of uncertainty is actually desirable while configuring MR&R projects. Organizations should determine if there is the possibility to accept uncertainty given the characteristics of their MR&R challenge. The attitude trade-off is also strongly related to the agility-dilemma, which influences the possibility to review and revise made decisions. If this opportunity is present, organizations may be willing to accept higher levels of uncertainty, as in future situations where more and new information is present, made decisions can be corrected.

5.6 EXPECTATIONS

Since MR&R projects and construction projects in general are often approached as a technical problem which mainly has technical complexities Bosch-Rekveldt [2011], solutions are often sought from this perspective. However, while most assets were built decades ago, the current functionalities perhaps do not meet the present needs [Hertogh et al., 2018]. Samset and Volden [2016] acknowledges the issue that projects in the earliest stages face difficulties in finding the underlying problem that provides justification and the needs that the project is meant to satisfy. This may result in a situation where the problem itself lacks sufficient analysis and alternative solutions may not be considered at all. This results in a major dilemma, as seeking other alternative solutions to solve this problem and thereby reconsidering the expectations of a projects requires increased effort and a different approach. Expansion of the perspective from mainly technical towards a broader context therefore changes the scope of the FED considerations [Busscher et al., 2015].

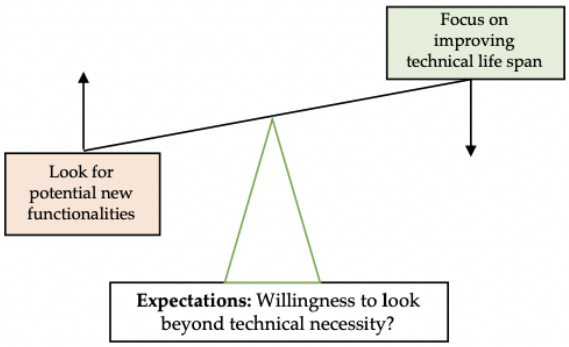


Figure 5.7: The expectations dilemma

5.6.1 The dilemma: Focus on the technical life span versus Including the bigger picture

Even though the FED phases and related decision-making is complicated by high levels of uncertainty [Salet et al., 2013], the question remains: Which (kind of) information is actually necessary for an organization to make substantiated decisions on the configuration of the MR&R projects? An organization can choose to focus on improving the technical life span by renewing or replacing the asset from a rather technical perspective. On the other side, the organization can see the MR&R challenge as an opportunity to revise the current functionalities of the asset. This could be functionalities regarding the usage, control, looks and so on. Extension of the expectations from a technical upgrade towards the revision of the current functionalities is related to the complexities as identified in chapter 4:

- (1) Requirements - Influence of organizational strategy
- (4) Asset conditions - Detail of condition assessment
- (9) Configuration methods - Diversity of configuration grounds
- (10) Configuration methods - Variety of configuration options
- (11) Configuration methods - Necessary effort to find configurations
- (12) Composition - Consciously including or excluding elements
- (14) Scope - Increased scope leads to more interrelations
- (16) Sequence - Options to postpone crucial activities

5.6.2 Relevant considerations

During front-end phases of large infrastructure projects, involved actors seem to have a tendency to look for potential factors which could decrease the chance of risks or consequences related to the fulfilment of pre-defined criteria [Volden, 2018]. Putting the prevention and mitigation of these threats on the agenda is a matter of course. However, finding a successful way to deal with such complexities in MR&R projects is less straightforward. By having a tunnel vision on dealing with these risks and omitting external factors may lead to public dissatisfaction and opposition later on in a project [Bruzelius et al., 2002; Van Wee and Rietveld, 2013]. Westerveld and Hertogh [2010, p. 241] state that premature convergence, where: *"(...) a solution is chosen early in the procedure, thereby 'killing off' the many other options present at that point in time."* is undesirable.

On the contrary, instead of looking at aspects that may cause failure, one can also investigate opportunities to contribute to the success during the front-end phases. According to Heising [2012, p. 582]: *At the front-end of projects, opportunities are discovered, ideas are created, and the foundation for later project, portfolio, and, eventually, corporate success is laid.* By extending the perspective from: What risks for project failure are available? to: What opportunities for project success are present?, an extensive interpretation of project success can be developed. In line with this ideology is the concept of opportunity framing, developed by Bakker et al. [2016]. This approach is focused on understanding and defining opportunities that add (societal) value to infrastructure projects. By looking beyond the physical boundaries of a project, the solution space for decision making on projects can be enlarged and prevents "killing off" present options in the preparatory phases of a project [Westerveld and Hertogh, 2010]. Early on reduction of the solution space is undesirable, as the project will become path-dependent [2] and opportunities for improvement are unlikely to be developed [RI3, personal communication, December 10, 2019] [Van Wee and Rietveld, 2013].

In essence, MR&R projects arise due to the need of an intervention as the remaining technical life span is coming to an end. Together with the need to take action, the opportunity to revise the present functionalities emerges. However, the decision to adjust the expectations and investigate new opportunities regarding the use and looks of the asset influences the scope of the project. The decision to keep the focus on simply dealing with the current technical life span keeps the scope clear and foreseeable for the organization and persons in charge.

2 Path dependent refers to the dependency on previous outcomes rather than current conditions

5.7 AGILITY

MR&R challenges are dynamic environments prone to a wide diversity of uncertainties [Schraven et al., 2011]. As a project develops, present knowledge on the problem results in a situation where preferences and related requirements may differ over time [Neumann and Markow, 2004]. This creates a situation which makes decision-making a complex undertaking, as decisions are often made without full knowledge on the consequences of the made decision [Stahl and Cimorelli, 2005; Perminova et al., 2008]. As a response, projects may become overly focused on solving the perceived problem at the early stages of a project [Crocitto and Youssef, 2003]. To deal with this issue, the application of adaptive management can be used to handle change and uncertainty [Zandvoort et al., 2018]. Schwab et al. [2018] state that: *"Agility and future-readiness are key in a changing world."* However, including agility in the decision-making procedure may clash with the need of stability, commitment and routines in an organization [Lewis et al., 2014]. To deal with this issue, the agility dilemma is introduced. Agility in this sense, is related to the opportunity to iteratively take decisions and create room for future adjustments to deal with the present levels of uncertainty [Kato and Ahern, 2008].

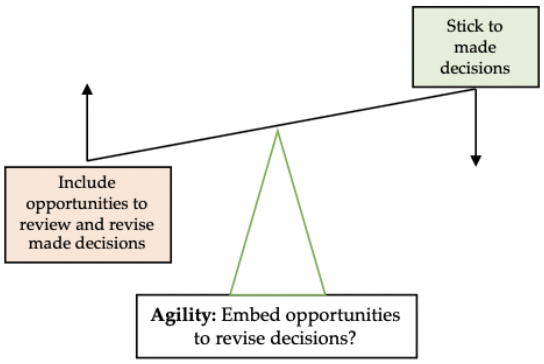


Figure 5.8: The agility dilemma

5.7.1 The dilemma: Stick to made decisions versus Including opportunities to review and revise made decisions

During the FED, numerous decisions have to be made regarding the procedure, the final configuration and intermediate decisions which lead to this decision [RI2, personal communication, November 22, 2019]. Given the necessary undertakings during the FED, it is a time-consuming and intense process which develops on previously made decisions. However, as the FED is characterized by high levels of uncertainties, the outcome of the made decisions may differ from the intentions. Presence of additional information after a decision is made, may lead to a situation which demands potential revision of the previously made decision. One option is to create room in the FED to adjust made decisions, while the other option is to not create these opportunities. Related complexities as identified in chapter 4 to this trade-off are:

- (13) Composition - Using a stage-gate system
- (15) Sequence - Premature convergence leading to path dependency
- (19) Adaptivity - Introducing GBC in a phased manner
- (20) Adaptivity - Revising the FED process for a new Tranche

5.7.2 Relevant considerations

The FED procedure often follows a developed procedure which builds on previously made decisions, as for example in figure A.3 and A.9 of VenR and PBK, respectively. Presence of this developed process results in clarity for the persons who are executing the activities during the FED [Gassmann and Schweitzer, 2014]. Decisions are made on the available information at that moment.

However, making decisions early on in the procedure may lead to sub-optimal outcomes as alternative solutions may arise while the project further develops [Westerveld and Hertogh, 2010]. This premature convergence of the solution space can be breached by including the opportunity to adjust decisions later on in the process, when more information and potential alternatives for the present problem are identified [NH2, personal communication, November 25, 2019]. Including agility in the FED procedure deals with the present uncertainty of changing conditions [Zandvoort et al., 2018]. The use

of stage-gate systems, as introduced by Cooper [1990], is a potential method to implement agility in the decision-making procedure. Archer and Ghasemzadeh [1999] state that the (intentional) projects which reach a certain gate should be re-evaluated at the same time new projects are being considered for configuration. In their opinion, this allows to create a configuration process which is adjusted to new project proposals, changes in strategic focus, revision to available resources and changes in the environment. By challenging the to-be made decision at certain gates in the FED procedure in the light of developed criteria, the quality of these decisions may be mirrored to present requirements. By challenging the to-be made decisions with updated criteria, performance is intended to be safeguarded according to the present knowledge at that point in time [Cooper and Sommer, 2016].

The impact of including adaptiveness in the FED procedure may differ over time, as the costs to make changes may increase as a project develops (as shown in figure 2.8 [Burke, 1999]). Thereby, adjusting decisions on the discussed dilemmas will become more complex with a rising institutional level where the dilemma is present. Changing a made decision on the segmentation dilemma will lead to a significant change which affects not only the MR&R environment, but the entire organization and its procedures. On the contrary, deciding to change the expectations towards the investigation of new functionalities of assets during the FED requires just some additional work for the project team in charge [RI2, personal communication, November 22, 2019]. Excluding agility from the FED procedure creates the opportunity for involved project teams which execute the FED steps, to gain experience and create standardization benefits [Sydow et al., 2004]. However, the chance that new information and configuration alternatives are revealed during the FED procedure is significant. Adjusting the project configurations to these changes will potentially lead to improved outcomes which were not achieved in absence of this information. Therefore, strong deliberation regarding the timing and positioning of agility opportunities is key for the functioning of the FED procedure and related configurations.

5.8 DESIGN OF THE DECISION-MAKING FRAMEWORK

An overarching element which prevails over all dilemmas is the trade-off whether to reduce or increase complexity of the configuration procedure. In general, two opportunities exists: simplification or complexification. Simplification is a commonly used method to deal with great levels of complexity [Scott, 1998]. By taming of issues and dividing them in smaller parts, they can be solved in a linear and project-based approach [Roberts, 2000]. Opportunities to reduce the complexity and ease decision-making during the FED were actively sought and even found. For example, VenR which had to deal with dozens of assets, kept the configuration of its projects relatively simple as the final configuration decision was limited to just an (element of an) asset. However, recent research by Joosse and Teisman [2020] stated that actively enlarging the complexity to manage complex issues can be beneficial to enhance the chance of successful public decision-making processes. In addition, simplification and project-based working leads to path-dependency, which restricts the 'space of possibilities' [Mitleton-Kelly, 2003]. Creation of comprehensive solutions by 'complexification' of the decision-making procedure is therefore called: path-creation [Joosse and Teisman, 2020]. But how can 'complexification' in MR&R challenges create certain paths? Put differently: What opportunities are present within MR&R projects to create a solution space which could lead to satisfactory project configurations?

In the end, it is about creating a balance between the level of complexity of the FED phases and the present opportunities related to the MR&R challenge. Observation of the cases may conclude that two important aspects which influence this balance are: the actual situation a public organization is facing and the intended outcomes of the configuration procedure. Creation of a balance can be done by adjusting the trade-offs to these case-related aspects which shape the FED configuration procedure. The discussed dilemmas all roughly present a trade-off whether to reduce or increase the complexity of the FED. Deliberate decisions on the presented trade-offs in the light of the present conditions and requirements should be made to find comprehensive balanced solutions as described by Joosse and Teisman [2020]. Increasing the complexity to a maximum amount may also increase the opportunities for comprehensive solutions, but also requires an increased 'span of control'. Thereby, if the decision-making process gets too complex, time may be wasted on irrelevant issues [de Bruijn and Dicke, 2006]. Since the identified dilemmas are presented as trade-offs which can be made by the public organization in

charge, observance of the present span of control within an organisation should influence the decisions to make certain trade-offs to keep the FED manageable and focused on present requirements.

5.8.1 Interrelations

As mentioned in the introduction, the dilemmas related to the FED of MR&R projects takes place at several institutional levels. This resulted in the image as shown in figure 5.1. The institutional level where a dilemma is present also reflects the level on which the trade-offs have to be made. Besides the corresponding institutional levels, the dilemmas also interact in other ways which will be explained in the upcoming clusters:

Cluster 1 - Context of the FED

Jointly, the segmentation, interfaces, expectations and agility dilemmas shape the context of the FED (as shown in figure 5.9. In general, the FED context sets the opportunities to create asset transcending benefits. By determining whether the FED takes place in an enclosed department or program, the demarcation of the MR&R related projects within the organization is identified. In relation to this, the interface dilemma determines whether the MR&R context is secluded from the development of non-MR&R projects. Lastly, on an asset level it is determined whether the FED procedure only focuses on improvement of the technical condition of the assets or also seeks opportunities to adjust current functionalities of the asset. Altogether, making decisions on these three institutional levels can determine the amount of elements and related interrelations within the FED. On one side, enlarging the FED context influenced the amount of configuration opportunities and potential benefits which can be created. On the other side, an increasing FED context also increases the span of control as the amount of considered elements and interrelations grows as well. Opportunities to review and revise the made trade-offs related to the FED context will have varying impacts. Whereas the decision to adjust expectations requires some additional asset related assessments, revising the decision to segmentate MR&R activities from the rest of the organization has substantial effects on the entire organization related to its structure and procedures. The effect of the agility dilemma therefore seems to have different proportions on the entire FED context and the involved organisation.

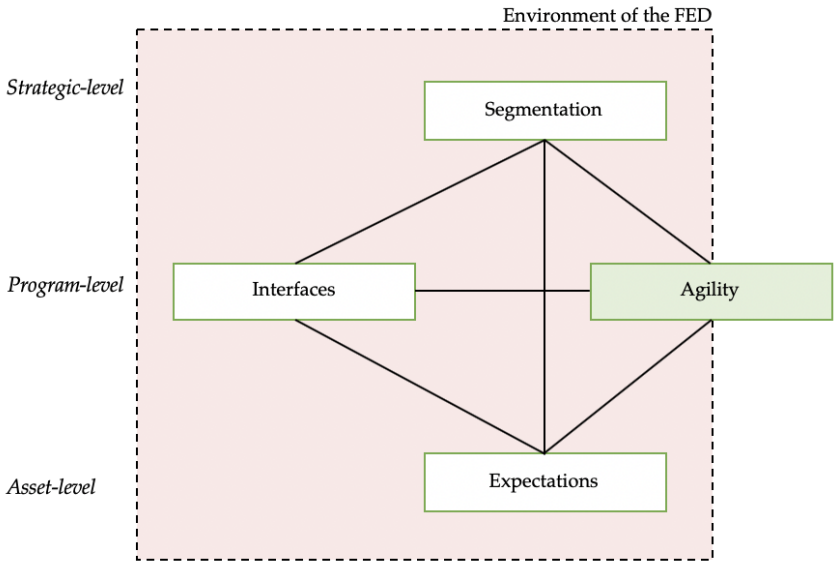


Figure 5.9: Dilemmas setting the FED context

To emphasize the interrelations within the procedural cluster they are briefly stipulated:

1. Segmentation - Expectations: Setting the context and purpose of the FED
2. Segmentation - Interfaces: Secretion or integration of MR&R activities from the rest of the organization

3. Segmentation - Agility: Opportunity to adjust the segmentation of the MR&R context
4. Interfaces - Agility: Opportunity to revise the interface seeking with non-MR&R projects during the FED
5. Interfaces - Expectations: Determine the magnitude of potential design alternatives for an (group) of assets
6. Expectations - Agility: Opportunity to expand the scope of MR&R interventions

Cluster 2 - Procedure during the FED

Next to the dilemmas which shape the outlines of the FED context, figure 5.10 visualized the dilemmas which influence the followed procedure during the FED. By determining whether the FED will be carried out for all 'MR&R-needy' assets individually or simultaneously the amount of separate FED-processes will be determined. Another key element of the procedure is the decision whether compromises among the present requirements are intended to be sought or the authority in charge decides that some requirements simply prevail over others. This logically influences the complexity and duration of the FED procedure. From an asset perspective, public organizations should investigate whether they (can) accept certain levels of uncertainty during the configuration procedure. Dependent on the decision, the procedure will have a certain emphasis on information accumulation during the FED. Adjustments to these procedural dilemmas are related to the decision in the agility dilemma. However, changing the chosen procedural decisions affects the earlier mentioned standardization benefits [Sydow et al., 2004]. As it takes time for an organization and involved employees on different institutional levels to get used to a certain procedure, changing the procedure will have effects of the functioning of the FED as a whole. Lastly, the dilemmas within the cluster interrelate as well, which will be discussed in the following overview:

1. Agility - Integration: Opportunities to adjust scope of the FED over time.
2. Agility - Attitude: Influencing uncertainty regarding the development of made decisions by including the ability to revise them.
3. Agility - Compromise: Opportunities to adjust preferences to changing demands
4. Compromise - Integration: Determine amount of potential trade-offs among requirements
5. Attitude - Integration: Opportunities to seek configuration options on varying grounds and conditions.
6. Attitude - Compromise: Use compromise to express preferences in levels of uncertainty.

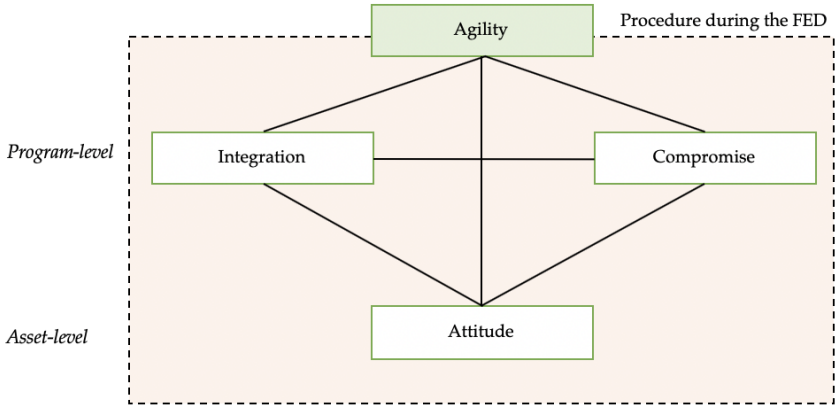


Figure 5.10: Dilemmas influencing the FED procedure

5.8.2 Overview of the framework

Together, the context and the procedural clusters determine the content of the decision-making framework, as presented in figure 5.11. Public organizations in charge of their MR&R challenge have the opportunity to make trade-offs on the indicated dilemmas, in order to adjust their FED to their objectives and values. The two clusters are strongly related as made decisions on a dilemma in the contextual cluster has consequences on the trade-offs on other dilemmas within the procedural cluster. For example, the decision to segmentate the MR&R environment in a separate division affects the trade-off regarding the attitude, as a separate MR&R department improves the potential to create a learning environment to decrease asset related uncertainties. The interfaces and integration dilemmas are also related, as they jointly determine the amount of interrelations and elements are to be simultaneously considered during the configuration process, which has significant effect on the present span of control.

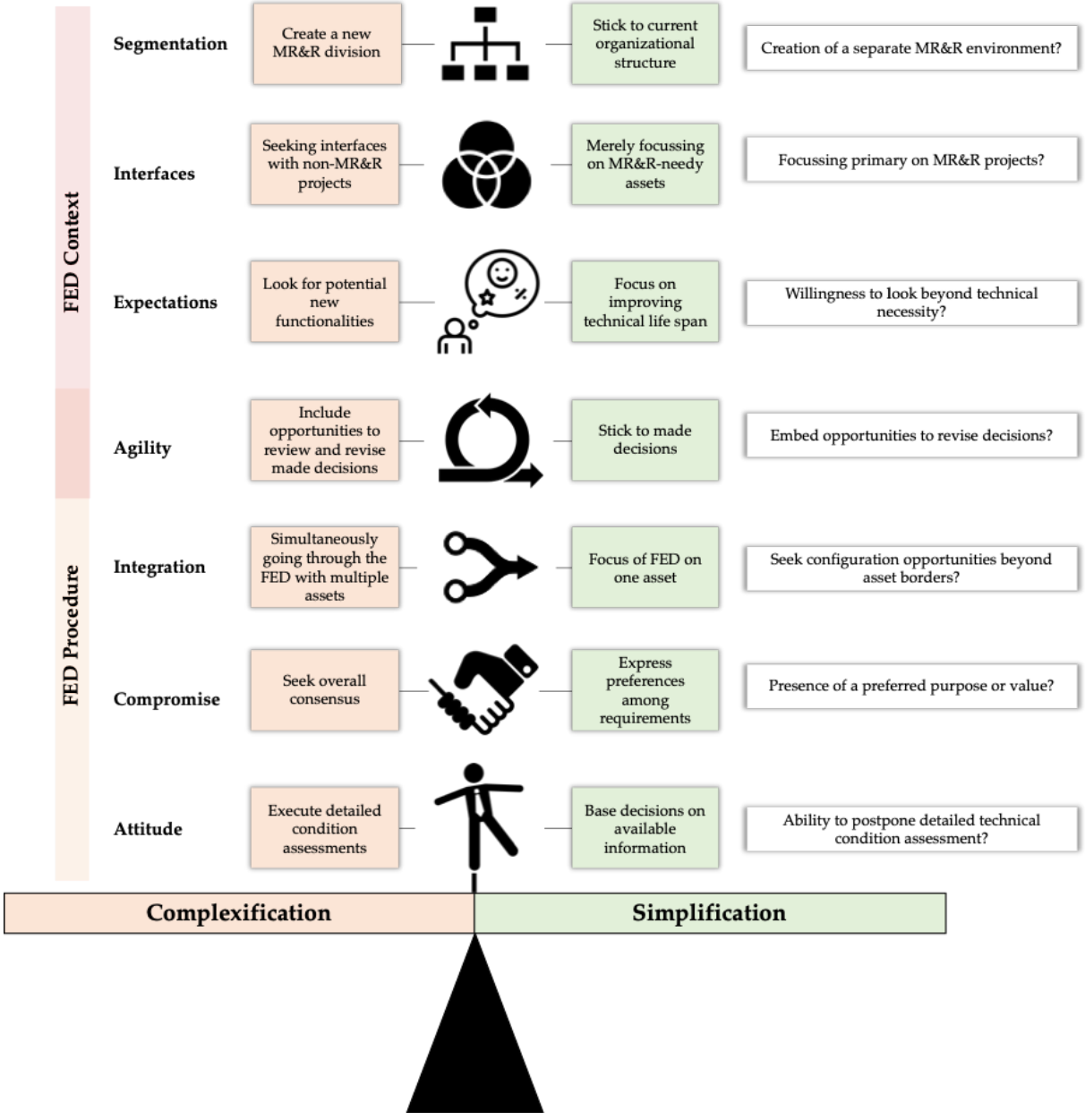


Figure 5.11: Overview of the decision-making framework

Indication of the discussed dilemmas creates the ability of public organizations to shape their FED procedure to the present requirements. The intention of the framework is to mirror an organization's

current FED process to the opportunities provided by the framework. By having an overview of the opportunities to adapt their FED process to their intended outcomes, organizational decision-makers may decide to correct the course.

However, regarding the implementation of the decision-making framework, some aspects remain underexposed. The timing of making the trade-offs is one of them. MR&R challenges will remain present during the coming decades, which results in a intermingle of present project phases of MR&R projects within one organization. Making a decision on the identified trade-offs may result in a change in the existing organizational structure, FED procedure and related resource demands. This may interfere with the present phase certain MR&R projects are in at that time. The timing of the trade-off decisions is therefore accompanied with a decision to draw a line which determines for which projects the made decision applies, in order to prevent haziness. Including the agility dilemma provides organizations with room for experiments related to their FED process design [Kato and Ahern, 2008]. Based on the effects of the implemented changes, an organization may decide later on to return to the former situation or to move along. This includes the opportunity to adjust the intended change on a selected part of the projects, before implementing it in the entire organization.

Second aspect is related to the authority and desirability to make decisions on the identified dilemmas. In the light of the earlier discussed principal-agent problem, decisions made by the principal are sometimes made in absence of information possessed by the agent [Laffont and Martimort, 2015]. Despite the indication of the present institutional levels of the dilemmas, the authority to make decisions on these levels is possibly located somewhere higher in the hierarchy. Presence of this potential obliqueness between information and decision-making authority is to be identified during the framework validation in section 6.2.

5.9 CONCLUSION

Consulting scientific research and investigating several MR&R cases raised more questions than it provided answers. Numerous ways to carry out the FED of MR&R projects were identified. However, as a knife blade cuts both ways, all approaches had their pros and cons, dependent on the intended outcome of the project. Therefore, the question to be answered in this chapter is:

Sub-question 3 *- "How could the FED process be designed to deal with MR&R projects in a fit-for-purpose manner?"*

By analyzing the identified complexities in chapter 4, the twenty complexities are reduced to seven substantiated trade-offs which unitedly shape the decision-making framework as shown in figure 5.11. These trade-offs should guide decision-makers in public organizations in the design of their FED of their MR&R challenges. Based on their present complexities, resources and requirements, organizations may adjust the design of their FED accordingly. In general, the decisions can be reduced to either reducing or increasing the complexity of the decision-making procedure. Reducing the complexity (e.g. simplification), aims to keep the scope foreseeable and limit the span of control. Increasing the complexity (e.g. complexification), aims to find solutions which would not be found if the FED would be carried out in isolation of other projects. However, increasing the complexity of the FED too much would potentially lead for severe challenges in the execution of the procedure as the amount of considerations and interrelations exceeds the present span of control.

Despite the broad analysis which contains the basis of this framework, the overview must be interpreted as a non-exhaustive list of dilemmas. The opportunity that other cases leads to different dilemmas is present, since other organizations may have different opportunities to configure their MR&R projects. Thereby, additional insights in decision-making authority, dealing with these dilemmas and potential consequences of making certain trade-offs are intended to be found, from a practical perspective. Therefore, to improve the ability to generalize the findings and the decision-making framework for MR&R challenges within the public transportation infrastructure domain, the next chapter is focused on validating the framework.

6 FRAMEWORK VALIDATION

Previous chapters combined both scientific literature and empirical insights to investigate potential ways to configure MR&R projects to create fit-for-purpose outcomes. In the end, seven dilemmas were found which jointly create an overview of the possibilities public authorities have in the creation of the solution space. This solution space indicated the potential configurations which could be developed to create comprehensive outcomes and transcend asset borders. The aim of this research is to create a decision-making framework which indicates the present trade-offs regarding the configuration process and is operable for all public authorities in the transportation infrastructure sector. However, to test the functioning of the developed decision-making framework it needs to be mirrored to existing situations and real-life MR&R cases.

In order to test the decision-making framework and the related trade-offs, it will be tested and validated. The test will be done by creation of an experiment in an existing case. To further validate the framework, it is reviewed by a group of experts which work with MR&R challenges on a daily base. Based on their experience, the framework is reviewed and potentially revised. Altogether, the two methods are intended to improve the validity of the decision-making framework.

6.1 EXPERIMENT

6.1.1 Introduction

The functioning of the decision-making framework will be tested by translating the trade-offs to a FED process design. Based on the present conditions, requirements and complexities of the case, the trade-offs will be made and explained. After the explanations are provided, the decisions will be transformed into a FED process to create potential configurations. The reason behind this experiment is to mirror the developed framework in practice. In formal terms, the to-be executed experiment is an imitation instead of an experiment, as this imitation does not meet all five requirements of an experiment as described by Verschuren et al. [2010]. Since experiments are often executed in a laboratory setting, this imitation experiment aims at finding new insights of applying alterations to the present FED process. By creating a FED process out of the present dilemmas and testing the configuration process, the completeness is tested and potential shortcomings are intended to be found.

The imitation experiment will be based on an existing case: Tranche 4 of the VenR challenge of Rijkswaterstaat, as deliberately analyzed section A.1. Based on the characteristics of the case, the identified dilemmas will be mirrored and translated to a process design. An existing MR&R case was chosen, since the FED process creation and the outcomes of the configuration process are easier to discuss compared to a fictive case. First, explanations regarding the leading principles of the to be developed FED process will be provided as a translation of the decision-making framework. Based on these leading principles, the design of the FED process will be developed and explained. Next, an experiment regarding the configuration of MR&R projects will be executed, based on the developed process. The outcomes of the experiment will be discussed afterwards.

6.1.2 Leading principles

Based on the characteristics of Tranche 4 as explained in Appendix D, decisions regarding the identified dilemma's are made. These decisions are based on the discussed considerations in chapter 5. An overview of the made decisions is visualized in figure 6.1. As can be seen, the decisions are not all focused on increasing the complexity of the FED process, to keep the interfaces and to-be considered

elements in balance with the purpose of the FED process. The rationale for the made decisions are explained in the subsections below.

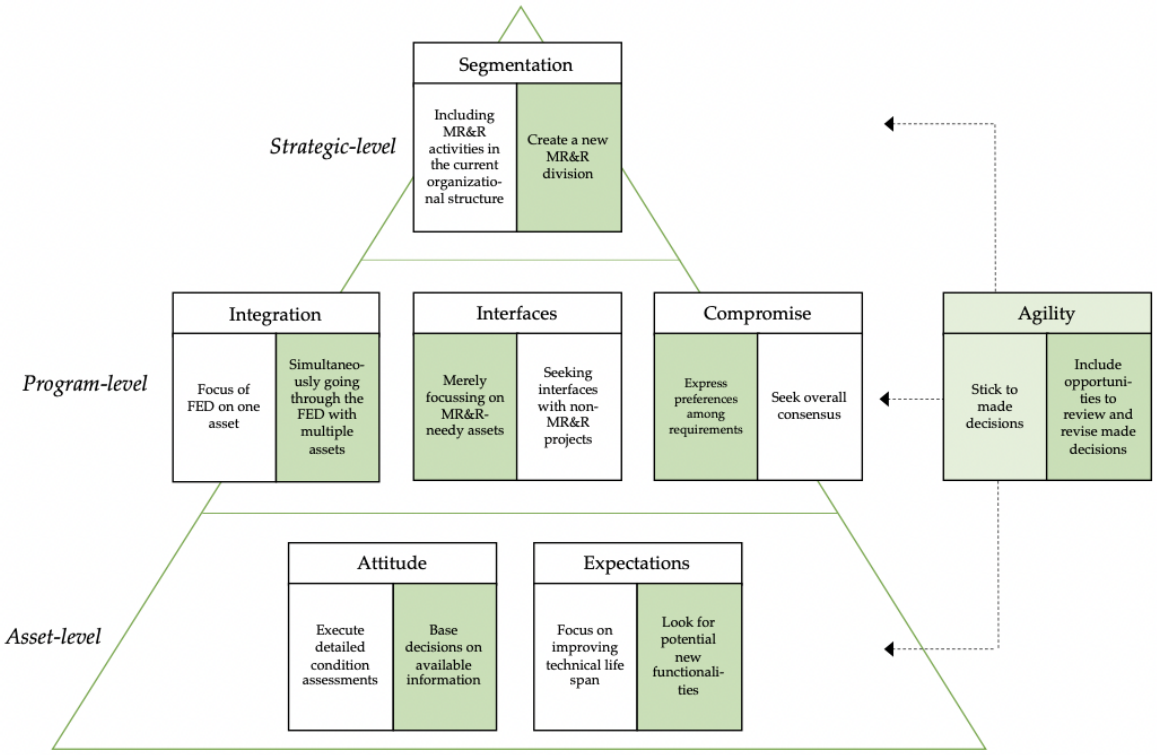


Figure 6.1: Overview of the made decisions for the VenR Tranche 4 case

Segmentation: Empowering knowledge while staying in control

How to create a situation where the necessary (intangible) information, is actually present at the people with the decision-making authority? The cases showed a great diversity in types of coordination of their MR&R challenges. From outsourcing (PMO) to programmatic control (PBK and KARGO) and in-line management (VenR), all cases seemed to have a different organizational structure. Combining the (tacit) knowledge of the asset managers and simultaneously having an overview of the current MR&R challenge of an organization and the authority to make decisions, is intended to be create by a programmatic control structure which is similar to the PBK case in Amsterdam. By having a MR&R team (reffered to as: Team MRR) with an autonomous MR&R board within Rijkswaterstaat, the decisions-making authority is to be located at the persons close to the content of the program. Within Team MRR the entire FED process is controlled and coordinated. By having direct links with all asset managers, the creation of a clear and streamlined procedures to receive all relevant asset information is to be developed. Given this chosen structure, Team MRR takes care of all MR&R projects within the organization in a decisive and effective manner. Acknowledgement of the size of the future MR&R challenge of all public authorities simply requires a new organizational division, as the share of MR&R projects is increasing and require a clear and streamlined process to tackle these challenges.

Integration: Using opportunities of large-scale MR&R challenges per asset

The VenR case reflects high levels of complexity due to the intermingle of technical, societal, legal, financial and time related issues. Decision-making within KARGO was influenced by the content of 8 steel bridges, spread out over two regions. Expanding the content of the decision-making however led to certain advantages in for example terms of risk reductions and economies of scale. As discussed in section 2.2, there is a certain body of assets necessary to generate those benefits, which would not be possible to create if the focus was only on a single asset. However, to keep a balance within the FED process and not increase the configuration process to a simultaneous consideration of 40 trade-offs, it is

decided to integrate all similar assets in the configuration process. Since there are 11 different types of assets (bridges, tunnels, noise barriers, etc.) in Tranche 4, 11 parallel FED processes will be carried out instead of one. Downside of this decision is the fact that potential opportunities to find configuration opportunities of heterogeneous assets in the same area are limited. However, this decision should keep the process manageable and create sufficient opportunities to seek asset transcending benefits within the context of one asset.

For example, the effects of MR&R interventions on the MR&R-needy assets would logically affect the traffic flows in the region or on the corridor. Enlarging the perspective from one bridge towards all bridges within a region, could provide an outcome for this challenge. Joint planning of MR&R interventions would create opportunities to find comprehensive and tuned solutions, which would not be achievable if all assets would be managed individually.

Currently, it is hard to say what the consequences of the process designs and chosen integration of PBK and VenR are, as they are still going on at the time of this research and ex-post evaluations are limited. Therefore, it is hard to give a verdict regarding the exact effects of the decision to carry out the integrated process designs of both cases. Would using the portfolio characteristics of a Tranche really lead to new opportunities to configure MR&R projects? Probably yes. But is the increase in complexity really advantageous over the current process design? As KARGO showed significant leverage of using the program-based approach, this FED process will focus on finding similar opportunities throughout the MR&R challenge of Rijkswaterstaat.

Integration and interfaces: The principle of cell fusion

Setting the opportunities for new configurations is one, using the opportunities is second. In order to create configuration options, a shift from the infrastructure domain is made towards the biology domain. Cell fusion is a cellular process in which two or more cells merge into a new cell which combines the characteristics of those merged cells [Ahkong et al., 1975]. Creating opportunities for these cellular fusion events can be done by attributing certain matching criteria to the assets. The asset assessment criteria as shown in figure 6.2, can also be seen as the potential matching criteria. In addition, section C.3 provides a simplified and non-exhaustive example of the potential matches that can be created among several assets.

PASSPORT ASSET X:

Type of asset:	Bridge | Tunnel | Lock | Quay wall | Noise barrier
Materials:	Steel | Concrete | Wood | Combination
Type of work:	Superstructure | Substructure | Foundation | Installations
Urgency of intervention:	Low | Medium | High
Traffic rates:	Low | Medium | High
Location:	…
Corridors:	Part of : Road / Highway / Waterway
(…)	**(…)**

Figure 6.2: Example of the assessment criteria of an asset during the FED

The green circles in figure 6.3 symbolize the assets and the surrounding '+' , '$\hat{}$' and 'o' symbols can be seen as the matching criteria. Traditionally, asset managers within different regions seem to not cooperate in the light of their MR&R activities. In this proposed way, project teams working on bridge replacements in region West Netherlands North can cooperate with project teams in region Middle Netherlands, as they are both part of the same organization and simultaneously working on MR&R projects. Combinations of projects which would normally not be found due to geographical or conditional differences, are now to be found by using the cell fusion technology.

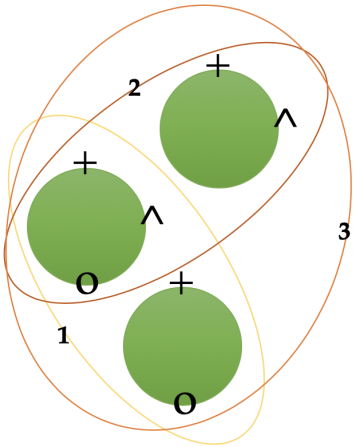


Figure 6.3: Concept of cell fusion to create matches between assets

Despite the new matching options which are created to potentially configure a portfolio or a program, a new challenge is created regarding the necessity to make a decision on a preferred configuration. Since an asset can simply be part of one project, portfolio of program, and potentially has multiple matches with numerous assets, final decisions have to be made on a final configuration.

Interfaces: Setting boundaries to the fusion opportunities

Working on MR&R projects starts by accepting that upgrading existing assets entails different complexities than building a new one. If links between greenfield projects and brownfield projects are actively sought, the scope will increase significantly. Different teams will need to find each other. While maintenance, renewal and replacement are significantly different compared to development of new infrastructure, it is questionable what the benefit of merger of activities are.

However, greenfield projects are also accompanied with sufficient nuisance to the surroundings and impact on the traffic flows. If potential MR&R projects are in a significant proximity to those projects, merger of activities may be beneficial given the fact that road users and nearby residents potentially prefer to face the negative effects once instead of twice. On the contrary, this is highly dependent on the content and timing of the potential project in charge. Merger of projects which differ significantly, like the renewal of the technical installations of a tunnel and the construction of a new highway differ to a great extent. Different kinds of expertise are required, which reduce the benefits of merging both projects into one. All in all, the potential benefits do not outweigh the increased complexity of merging all sorts of projects Rijkswaterstaat faces into the scope of the FED consideration. Therefore, it is decided that within the scope of the FED process only the assets which require an MR&R intervention are included for these 17 bridges which are part of the imitation experiment.

Compromise: Expressing guided preferences among requirements

As discussed in the case analysis of VenR in section A.1, a wide variety of requirements is present. However, considering all requirements during the FED process and related configuration would be a complicated task given the ambiguity and conflicting character of some requirements. Thereby, situations may demand the preference of requirements over others. For example, the Van Brienenoordbridge in Rotterdam connects the A16 highway and crosses the Nieuwe Maas river, with a daily passage rate of 230.000 vehicles (in 2015). Another bridge in Tranche 4, the Haringvlietbridge in Numansdorp connects the A29 highway and crosses the Haringvliet estuary, with a daily passage rate of 54.400 vehicles (in 2015). With having less than 25% of the vehicle traffic rate, the effect of closing of a (part of the) Haringvlietbridge for MR&R interventions has a different magnitude regarding the effect on the traffic flows compared to the Van Brienenoordbridge. Thereby, there are more assets near the van Brienenoordbridge in Tranche 4 which may affect the present of alternative routes during the MR&R works. Taken from this perspective, it would be thinkable to weigh the traffic nuisance requirement heavier compared to requirements related to sustainability or organizational processes, as indicated in

section 4.1.1. Therefore, it would be thinkable to express guided preferences, dependent on the situation. Additionally, the present requirements in Tranche 4 and potential ways to achieve them through configuration, are discussed in Appendix C.

Attitude: A two-phased process

In order to save time and effort during the FED, this decision aims to reduce the risks of making final decisions without having an exact picture of the present complexities. The common tread in all analyzed cases was that there is no questioning about safety. By first filtering out the projects which need immediate MR&R interventions, opportunities of path creation are sought with assets which actually have the ability to look for added value. Application of a 'two-phased processes' therefore aims to reduce the risks of configuration under uncertainty. Within this decision-making framework, the MR&R projects will first be filtered on a urgency-based criterion. Underlying thought of this decision is related to the sense of urgency which is related to some MR&R interventions. If an asset has a limited remaining technical life span and needs relatively quick MR&R interventions, the added value of 'complexification' is questionable.

Next to the earlier mentioned urgency assessment, to filter out the MR&R projects which don't have the ability to seek clustering benefits, the framework will include a condition assessment which is in line with the stated requirements. To seek potential matching criteria among assets which need a MR&R intervention without conducting extensive (technical) condition assessments, other criteria are to be tested. An important condition of these assessment criteria, is the relatively low effort needed to actually determine the value of the criteria. By having criteria which are relatively easy to determine, potential configuration options can be sought relatively quick and easy. KARGO showed that saving time and effort during the FED on condition assessments are preferable, as the assets face an end of their technical life span sooner or later and time consuming procurement and technical condition assessments lay ahead. A balance is therefore to be found between the necessary effort to determine the criteria and the usefulness of the criteria to determine potential MR&R project configurations on. To provide an example, figure 6.2 shows a potential overview of a condition assessment which can be executed during the FED of a MR&R challenge.

Gathering this information is intended to require relatively little effort, compared to detailed condition assessments, but still provides enough criteria to potentially configure MR&R projects. By creating a passport of all assets within a public organization which are known to reach their technical life span in the nearby future, finding matches like the 8 bridges in KARGO becomes more likely.

Expectations: Create opportunities for new functionalities

Together with the necessity to renew or replace an asset, the opportunity to revise its current functionality will be exploited in the imitation experiment. As most assets were build decades ago, current desires regarding future functionalities related to 5G and 'Internet of Things' demand the opportunity to make the assets future-proof [Rijkswaterstaat, 2019b]. Logically, this shifts the technical perspective of the MR&R process from primary renewing or replacing the asset, towards a broader point of view with more considerations and necessary explorative activities . However, since some new functionalities are desired to be implemented across all assets of Rijkswaterstaat, executing them simultaneously with the necessary MR&R interventions can be seen as an opportunity.

Agility: Iterative selection process with temporary configurations

Preferences may simply change over time, due to a legion of reasons. Within the imitation FED process, it is therefore decided to implement room for agility. During the process, configurations are to be made, based on the present requirements and found matches between the assets. Instead of searching for simultaneous solutions for all 40 projects within Tranche 4, potential configurations can be created and temporarily stored without starting the execution. Given the importance of the present requirements at that point, potential configurations can be temporarily saved, until all assets are configured. Based on the first saved potential configuration, the remaining assets can be returned to a new 'round' where the process of making new potential configurations is started. This iterative process can be continued,

until configurations are found which meet the stated requirements to a satisfactory extent.

By updating the preferences among the requirements with every configuration 'round', the potential configurations are checked with the updated requirements of that moment. Instead of immediately making all configurations out of the set of projects within Tranche 4, this process aims at finding fit-for-purpose outcomes in the best way through operating adaptive. Not including this agility in the process, would potentially not lead to the same configurations, as preferences are likely to change given the creation of the potential configurations. On one side, including the agility in the process will take more effort and therefore time during the FED to find the potential configurations. On the other side, constantly updating the requirements and relating the configuration to this is intended to create better fit-for-purpose configurations on the long run.

Overview of the made decisions

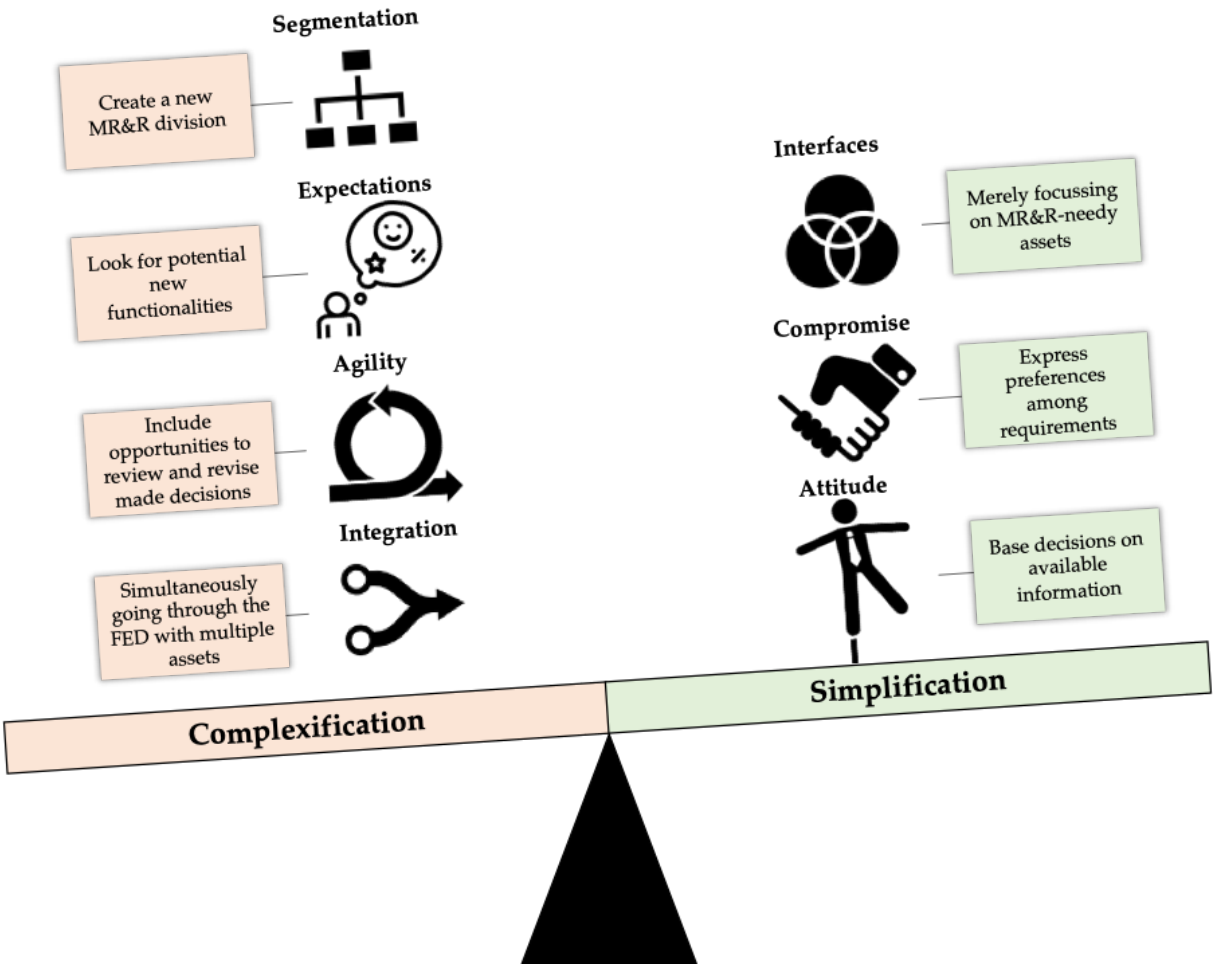


Figure 6.4: Overview of the made decisions for the VenR Tranche 4 case

In the end, the following decisions are made which deliberately 'complicate' the FED process:

- **Segmentation:** Creation of a separate division
- **Integration:** Merging all MR&R activities of the organization into the responsibility of this division
- **Expectations:** Search for new functionalities for the assets
- **Agility:** Creating potential configurations by an iterative process and updating requirements

Whereas the following decisions aimed to limit the complexity of the FED process:

- **Integration:** Only integration of corresponding assets in the FED process
- **Interfaces:** Keep the focus only on MR&R projects
- **Compromise:** Express preferences among present requirements instead of constantly seeking consensus
- **Attitude:** A two-phased approach: seek configuration benefits on non-technical requirements

By both complicating and simplification the FED process, a balance is intended to be found. On one side, the environment is consciously kept large. Yet, also some boundaries to the FED process are implied to keep the process manageable for the persons who actually have to carry out the FED process. As shown in figure 6.4, the decision create a little imbalance. While the final decisions result in a situation where more emphasis is on the complexification of the FED process, this may result in difficulties while creating fit-for-purpose configuration. To investigate the consequences of the made decision, the following subsections will create a FED process design and try to configure executable MR&R projects, based on the made decisions as shown in figure 6.1.

6.1.3 FED process design

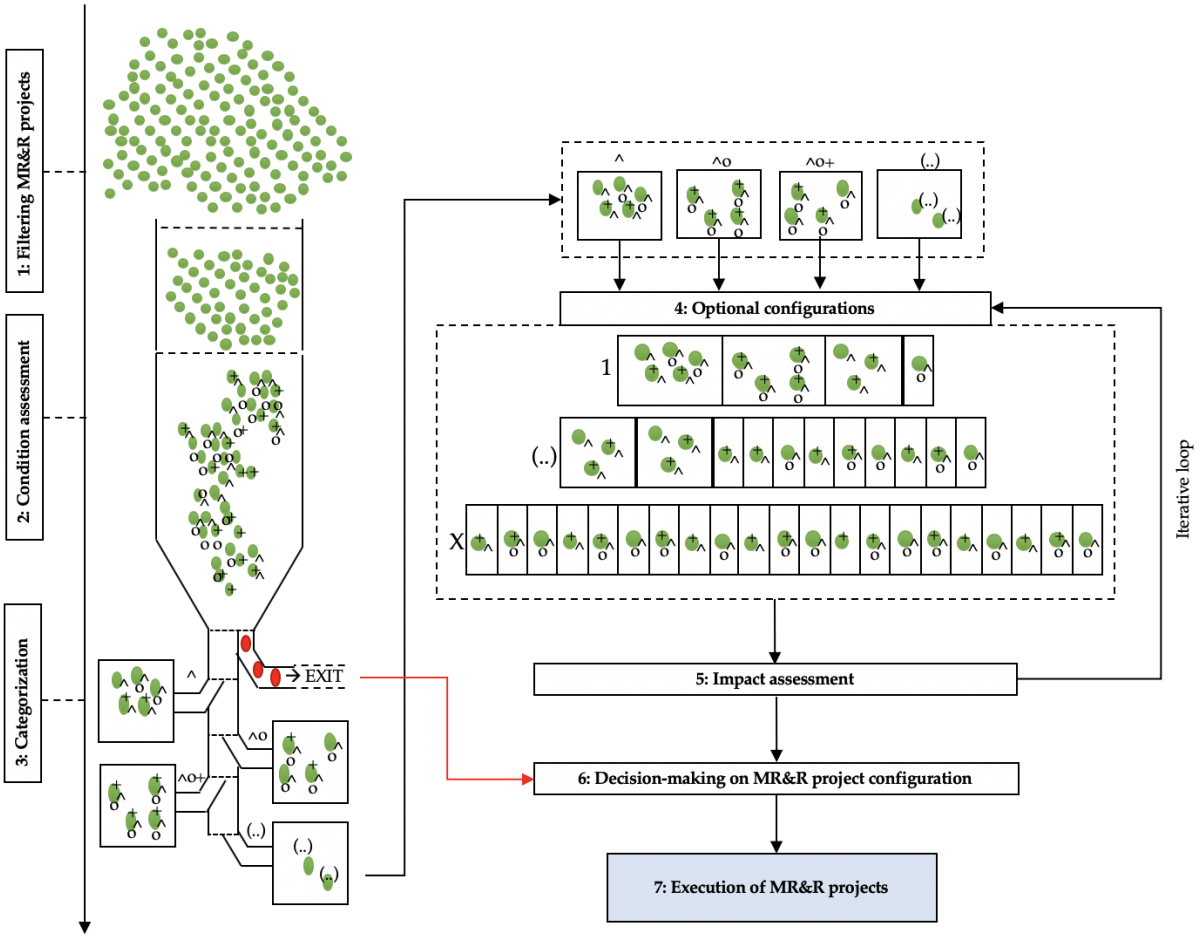


Figure 6.5: Overview of the provisional decision-making framework

Starting with the end, the purpose is to develop a FED process design which is applicable to guide 'MR&R-needy' assets trough the FED and ultimately result in a project which is ready for further development. As observed in the cases in chapter 4, Rijkswaterstaat deals with a bunch of assets which need a MR&R intervention in more or less the same time frame. Determining how these assets can be transformed into projects which are ready for further executions in a fit-for-purpose manner is therefore key. The configured MR&R project can be seen as the product and the antecedent FED phases

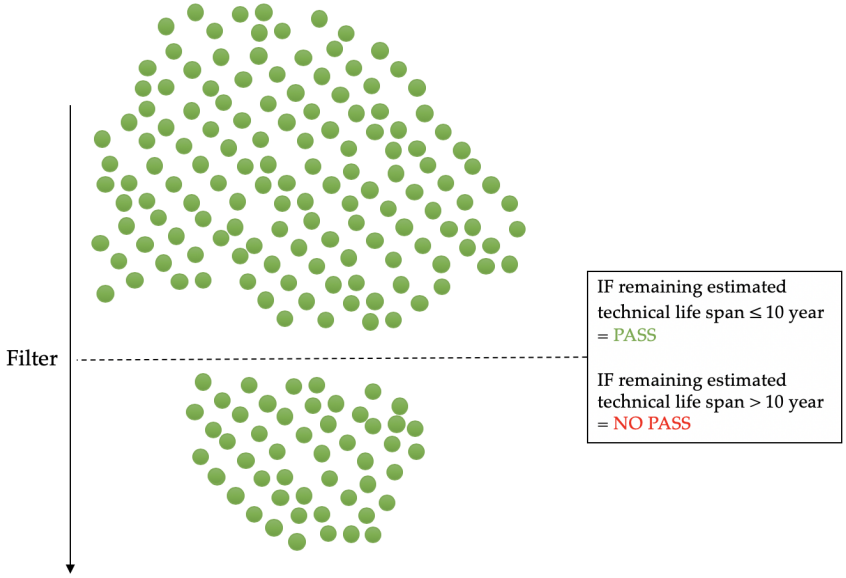
as the process leading to this product [Sperry and Jetter, 2009; Edkins et al., 2013]. Without a proper process, achievement of a satisfying product would be hard and vice versa [Karydas and Gifun, 2006].

However, in the paraphrase of fit-for-purpose lurks a complicated challenge, as it intends to fit the process and product to the current project characteristics like complexity, size and requirements [Weijde, 2008]. Since these characteristics may differ for every situation, setting up a process design and configuring MR&R projects accordingly is difficult with an one-size-fits-all approach. Therefore, the aim is to develop a FED process which exists of clear steps with a set sequence and related trade-offs, which still leaves enough room to adapt to the unique situation a public authority is facing. By doing so, the process design is intended to be generalizable for all public authorities which face MR&R challenges in the transportation infrastructure sector and provide the ability to both set up the process and configure the projects in a fit-for-purpose manner.

Altogether, the discussed design principles resulted in a FED process (as shown in figure 6.5) which has the intention to deal with the complexities of Rijkswaterstaat. While the decision-making process regarding the configuration of MR&R projects takes place during the FED, this framework intends to figure as a method to execute the FED1 (Assess) and FED2 (Select) phases. The explanation of the framework will be done in a step-wise manner.

Step 1 - Inventory of current assets

To get an overview of the 'MR&R-needy' assets within the organization, all assets need to be checked in a general matter. All asset managers which are in charge of the daily maintenance of their assets are asked to share the information of the assets in their area. A team, which operates on an organizational and region overarching matter (referred to as: Team MRR), checks these submissions of the asset managers whether the assets are actually in the need of a MR&R intervention within a set time frame. As an example, a remaining technical life span of 10 years has been chosen in figure 6.6. These assets are bundled in a portfolio which share the need of a MR&R intervention within a set time frame.



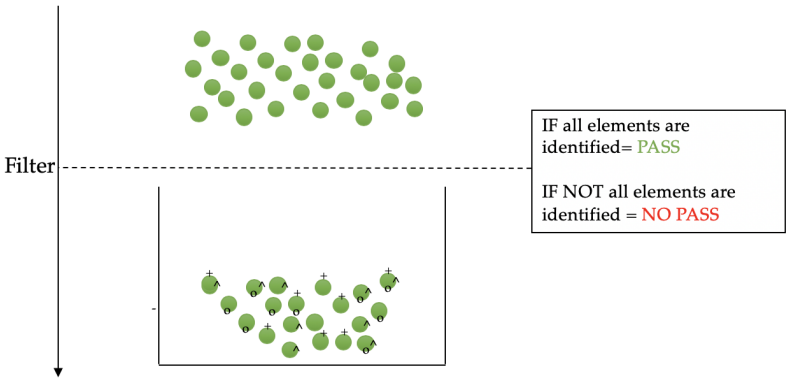
Step 1: Filter all assets which reach the end of their technical life span within 0-10 years

Figure 6.6: Separating the MR&R-needy assets in an organization

Step 2 - Set potential matching criteria

To get a better overview of the asset which are in the developed portfolio, Team MRR has developed a set of assessment criteria which together create an 'asset passport'. These assessment criteria are sent to all responsible asset managers in the same format, to get an improved insight in the actual conditions of the assets. The assessment criteria are composed in a way, that potential matches between the assets

can be found. Development of the passport criteria is based on the present requirements which were stated for VenR Tranche 4. Once the condition assessments are returned by the asset managers, Team MRR can set the matching criteria. Based on their passports, every asset gets a bunch of matching criteria before they proceed to the next step of the framework.

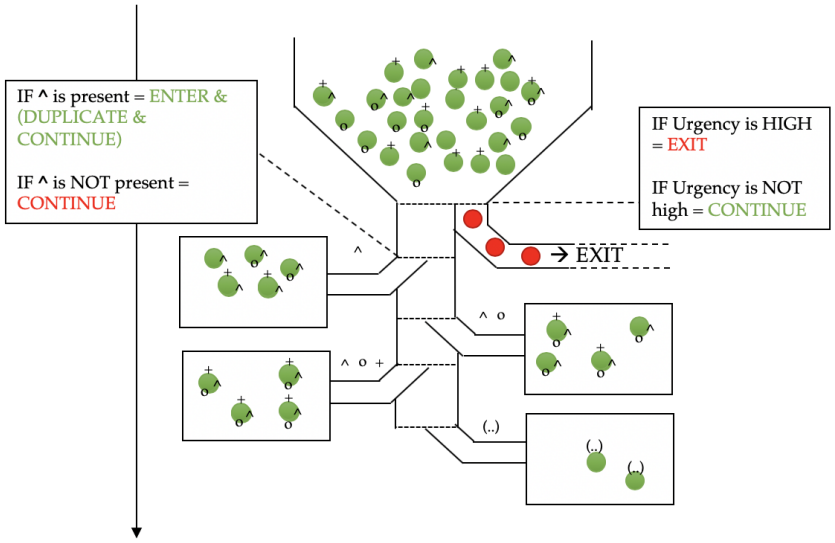


Step 2: Create a passport for all 'MR&R-needy' assets on key elements and set matching criteria

Figure 6.7: Identification of key elements and setting matching criteria

Step 3 - Categorization of assets

Based on the assessed matching criteria, the assets within the selected portfolio are filtered. The first decision related to the configuration of MR&R projects is related to the urgency of an MR&R intervention. If the level of urgency is high, an asset is withdrawn from the configuration process and will be executed on a project-basis. The other assets continue to the filtering process. During this process, all assets which have the same (combination of) matching criteria will be bundled into a certain box in a tentative manner. As assets have multiple matching criteria, the option exists that they are part of multiple boxes, as shown in figure 6.8. The development of these matching boxes can be one or a multitude of criteria. These boxes will be used as input for the potential configuration options, which are developed in the next step.



Step 3: Decision moment 1 – Categorization of assets

Figure 6.8: Filtering process

Given the absence of complete information, decisions in the first three steps of the process are made in a matter that satisfies the decision-maker given their stated criteria. The process follows a relatively logical and multi-step process of 'quick-and-dirty' condition assessment. The decision to pursue the configuration process in step 3 is based on these condition assessments, which provide a rather generic view on the urgency of an MR&R intervention. As safeguarding the safety of an asset is always top priority, additional configuration opportunities are not sought and the assets will be executed on a single project-basis. Despite the potential configurations this assets could be part of, the process draws a hard line when it comes to safety.

Step 4 - Create an overview of the potential configurations

Based on all the boxes which embody a potential configuration of a MR&R project or program which is ready for further execution, potential configuration scenario's can be developed. As one asset can only be part of one MR&R project or program, multiple scenario's are to be developed. These potential configurations are input for the impact assessment in the next step. An overview of the potential configuration opportunities and potential drivers of the configuration process is provided in Appendix C.

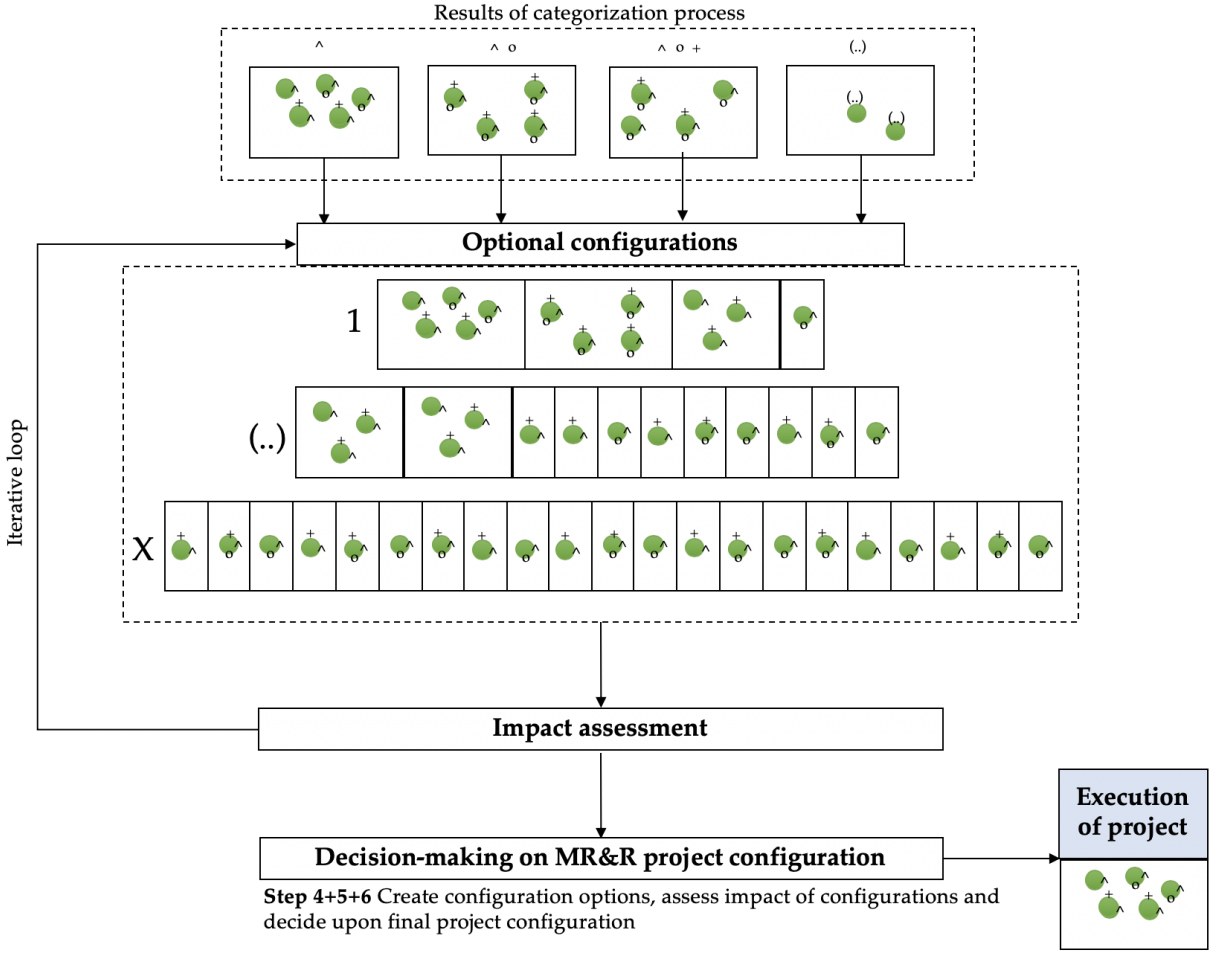


Figure 6.9: Creation, assessment and deciding upon configuration of MR&R projects

Step 5 - Assess impact of potential configurations on requirements

In the end, certain decisions regarding the configuration of MR&R projects and programs have to be made. But how to do this, as there are multiple scenarios to choose from? The boxes and related configuration options are a result of the condition assessment in step 2. These condition assessments were developed to provide sufficient grounds for potential matches which are in line with the requirements

of the organization and related MR&R challenge this framework is dealing with.

Evaluation of the scenarios on the present requirements like for example accessibility, can be done by checking the optional configurations where assets with high traffic flows are merged in one box in the scenario. Potentially, these assets can be configured as a formal goal-oriented program which share the objective of safeguarding the traffic flows within the operational region of the public authority. More detailed options to make decisions on the present configuration options will be discussed in the experiment in chapter C.

While an asset can only be part of one project or program, the provisional decision on a configuration influences the remaining configuration options. Therefore, an iterative loop from step 5 to step 4 is included in the framework. Given these provisional decisions, new configuration scenario's can be developed and assessed accordingly, until a public authority has the idea that the projects are configured in a fit-for-purpose manner. By including this iterative, the public authority has the opportunity to create a balanced portfolio of MR&R projects and programs which comply to the present requirements. If a MR&R program which mainly focuses on sustainability already is provisionally configured, the consequent configurations can potentially focus on other requirements. By having an overview of the provisional configurations and the present requirements, the outcome is intended to create fit-port-purpose outcomes.

Step 6 - Final decision on project configuration

After all assets are provisionally assigned to a certain MR&R project or program that meets the present requires in the best way, the final decision on the overall configuration is made. This set of configurations will be final and ready for execution in the consecutive project phases.

6.1.4 Test results

Given the chosen process design, the functioning of the process is tested by executing the process for the bridges in Tranche 4. It is chosen to only test the process for the bridges, since the decision was made to execute the FED process for all kind of assets separately and this is the largest share of projects within Tranche 4. Present requirements, ways to achieve them and the overview of the bridge's passports are presented in Appendix C. Unfortunately, not all desired data of all bridges was available at the time of this research. Based on the information which was present, three potential configurations are created, based on the developed process as described in the previous subsection:

1 - Cluster based on corresponding MR&R compartments which need intervention

1. **Movable:** (1) Van Brienenoordbrug, (4) Giessenbruggen, (5) Haringvlietbrug, (6) Draaibruggen Lorentz / Stevin, (8) Buitenhuizerbrug, (9) Brug over de Westerwolsche AA, (12) Papendrechtse brug, (15) Koningsbrug, (16) Hooivaartsbrug

2. **Fixed:** (3) Ijsselbrug, (17) Brug 1 Nederweert

3. **Unknown:** (2) Brug over ringvaart Badhoevedorp, (7) Schellingwouderbrug, (10) Brug over Goereese sluis, (11) Algerabrug, (13) Erpsebrug, (14) Kelperbrug

Merging bridges with corresponding needs in MR&R interventions primary aims to achieve performance benefits. By having a mutual compartment which needs to be either renewed or replaced, knowledge of one project can be used in the development of other projects which face similar challenges. Logically, there are also significant differences between the individual assets. Therefore, development of a program can function as a 'shared knowledge centre' as mentioned by van Buuren et al. [2010], where the knowledge is stored, whereas the decision regarding the execution of the MR&R interventions can be made later on. Given the significant amount of bridges of which the necessary MR&R intervention is lacking, it is hard to give a verdict about the size of the clusters. If all these bridges seem to need a MR&R intervention, it may be wise to divide the entire group into smaller groups which have additional common conditions.

2 - Clusters based on corresponding location and MR&R compartments

Based on the location of the bridges and the (known) need for MR&R intervention, the following clusters can be made:

1. **Friesland / Combination:** (6) Draaibruggen Lorentz / Stevin, (15) Koningsbrug, (16) Hooivaartsbrug
2. **Gelderland / Fixed:** (3) Ijsselbrug
3. **Groningen / Combination:** (9) Brug over de Westerwolsche AA
4. **Limburg/ Fixed:** (14) Kelperbrug, (17) Brug 1 Nederweert
5. **Noord-Brabant / Unknown:** (13) Erpsebrug
6. **Noord-Holland, Combination:** (2) Brug over ringvaart Badhoevedorp, (7) Schellingwouderbrug, (8) Buitenhuizerbrug
7. **Zeeland / Unknown:** (10) Brug over Goereese sluis
8. **Zuid-Holland / Combination:** (1) Van Brienenoordbrug, (4) Giessenbruggen, (5) Haringvlietbrug, (11) Algerabrug, (12) Papendrechtse brug

Instead of only separating all bridges in a corresponding MR&R intervention, this configuration aimed to cluster bridges with a corresponding MR&R intervention and location in one cluster. This decisions therefore led to 8 separate clusters with a varying amount of projects, differing from one to five. All clusters consist of corresponding MR&R interventions which need to be executed, sometimes combined with additional individual demands like a fixed, movable, mechanical or control MR&R demand per bridge. The bridges which lack present knowledge on the necessary MR&R intervention, are described as unknown.

3 - Cluster based on corresponding Chromium VI presence

Based on the presence of the dangerous presence of Chromium VI on the bridges, the following clusters can be made:

1. **(Likely) presence of Chromium VI on bridge:** (1) Van Brienenoordbrug, (3) Ijsselbrug (4) Giessenbruggen, (5) Haringvlietbrug, 6) Draaibruggen Lorentz / Stevin, (11) Algerabrug, (12) Papendrechtse brug, (15) Koningsbrug, (16) Hooivaartsbrug
2. **Unknown presence of Chromium VI:** (2) Brug over ringvaart Badhoevedorp, (7) Schellingwouderbrug, (10) Brug over Goereese sluis, (11) Algerabrug, (13) Erpsebrug, (14) Kelperbrug, (17) Brug 1 Nederweert
3. **Absence of Chromium VI:** (8) Buitenhuizerbrug, (9) Brug over de Westerwolsche AA

Instead of looking at the primary interventions which need to take place, an other critical element like the presence of Chromium VI is chosen to make configurations. Despite the various types, sizes, and locations of the bridges, the presence of Chromium VI can be a critical aspect related to the MR&R interventions. Given the risks of removing Chromium VI, it could be wise to approach these assets in an individual matter which is primary focused on the removal of Chromium VI. Potentially, new techniques need to be developed to remove it from the bridges which can only be done by a limited amount of contractors. However, necessity of such techniques is less relevant in the case of replacement, as the Chromium VI can be processed on an external and safe location. The decision whether an asset is renewed of replaced therefore determines the nuisance and the complexity of processing the Chromium VI. Bundling forces and developing an integrated solution is more (economically) efficient if the to be renewed bridges are merged into one program, instead of sough individually.

6.1.5 Concluding remarks

Based on the conditions, present requirements and complexities of VenR Tranche 4, the identified trade-off led to the FED process as shown in figure 6.5. Given the ever present complexity of uncertain technical conditions of the assets, the decision was made to exclude the necessity of this data in the decision-making process to a great extent. Instead of conducting time consuming condition assessments by expensive external experts, the imitation experiment showed that configuration of MR&R projects could also be executed on the basis of other (i.e. easier to assess) conditions. As the content of the assessment expands with geographical, material and traffic flow data, the basis for potential configuration options also expanded. This conscious 'complexification' is made, to create configurations which are more fit-for-purpose compared to configurations which only exists of one asset per project [Joosse and Teisman, 2020]. The design of the decision-making process in the developed framework tries to maximize the opportunities for new configurations through the attribution of matching criteria and using the principle of cell fusion. Based on the condition assessment (which is summarized in table C.1), the assets get several matching criteria assigned, which create the options to fuse with other assets, based on their corresponding conditions. Dependent on the preference among the present requirements, the matches can be weighed up against each other. As assets have multiple matching criteria, they can possibly be part of multiple potential configurations. Coordination of this entire process is done in a programmatic manner, by one coordinating MR&R team which has the mandate to make decisions and create the procedures to retrieve important asset conditions and trade-offs.

It was decided to leave out assets which face a high level of urgency from the configuration process, as safety is not arguable and needs to be safeguarded at all times. Based on the investigated cases, it is plausible that Rijkswaterstaat values certain requirements, except safety, more important than other requirements. Within the evaluation of potential configuration options, the configurations which jointly shape a program or project which aim to fulfill these requirements to the greatest extent could get a 'provisional configuration' status. Given the inability to include an asset in multiple permanent configurations, the remaining assets will be used to develop new configuration opportunities. This iterative process should in the end led to a set of project configurations which used the opportunities of a MR&R challenge in a fit-for-purpose manner.

In the end, the created FED process was tested and resulted in three potential configurations, based on easy-to-assess conditions. Despite the fact that the process was only tested for the bridges in Tranche 4, the outcomes showed the opportunities of the developed FED process and the underlying framework. Instead of the present used one-asset-one-project approach, the new process showed opportunities to create potential benefits which would initially not be found. This pinpoints the added value of the developed decision-making framework. Public authorities in charge can make their own decisions and develop and test their own FED process, which increases the opportunity to increase the solution space and find fit-for-purpose configurations. Changes to the developed framework are therefore considered not be necessary.

On the other side, the created process and configurations are a unrealistic representation of reality, as the presence of numerous decision-making authorities with potentially various interests is neglected. To identify the persons-in-charge which have the power to make decisions on different institutional levels(as presented in the decision-making framework), this will be one of the validation objectives. Thereby, the timing of the made decisions are presented as a clear and chronological order. In reality, decisions and separate processes will consist of a intermingle of processes instead of a linear sequence of developed process steps. On the contrary, having a process which functions as the standard procedure provides the involved persons with a required guidance to perform their tasks. Lastly, seeking potential configurations for 17 bridges simultaneously, demanded a significant effort as the amount of bridges, conditions and interrelations between these aspects created an serious amount of trade-offs. If public authorities in charge made similar decisions and try to find configurations for 17 bridges at the same time, they should be aware of the complexities related to this. Attributing weights to the present requirements (as presented in compromise dilemma) could however ease the process, as presence of preferences lead to clearer trade-offs.

6.2 EXPERT REVIEW

6.2.1 Introduction

The decision-making framework is developed on an analysis of scientific literature and empirical data from multiple MR&R cases. Based on the analysis, the insights were merged into a decision-making framework as shown in figure 5.11. In order to check the validity of the developed framework, it is presented and discussed with a panel of experts which are working with MR&R challenges on a daily base. The expert review had three objectives:

1. Completeness: Validate the content of the decision-making framework
2. Functioning: Validate the potential effects of to-be made trade-offs
3. Usability: Validate whether the decision-making framework is applicable for the persons involved

The expert review was part of a knowledge sharing event between the Municipality of Amsterdam and the West Netherlands North division of Rijkswaterstaat. The aim of the event was to get insights in each others dilemmas regarding the development of their MR&R challenges and to find potential overlap among these challenges. Attendees of the event were the PBK Program Board of the Municipality of Amsterdam as shown in figure A.8 (Director Strategy, Director programming and acceleration execution, Director surroundings, Director safety, knowledge and advice and Director management and control) and the IPM team (Project manager, Project controller, Surroundings manager, Contract manager and Technical manager) of the VenR division in the West Netherlands North region of Rijkswaterstaat. Both teams are responsible for the management of the MR&R challenge within their organization (PBK) and region (VenR WNN).

6.2.2 Method

The expert review consisted of multiple aspects:

- Presentation of the research and the decision-making framework
- Feedback on the framework by asking questions on the mentioned objectives
- Joint discussion on the framework and the provided feedback
- Mirroring the framework to the discussed dilemmas by the organizations during the rest of the event

Given the schedule of the event, time to validate every trade-off of the framework into detail was not available. Therefore, the validation was focused on mirroring the framework to the situation both teams encounter and provide rough answers on the objectives. Therefore, the results of the expert review are a useful contribution to the validity of the framework but do not guarantee full validity of the developed framework. Future validations with more detailed questions and a different setting with other organizations would further improve the validity of the framework. Nevertheless, having the opportunity to perform an expert review in this formation is a great contribution of the validity of the framework since the attendees actually have the decision-making authority to oversee the FED process and implement adjustments.

6.2.3 Results

The results of the expert validation will be discussed according to the stated objectives regarding the completeness, functioning and usability of the framework.

1 - Completeness

The first objective was to reflect the dilemmas on the present organizations. After an explanation of the separate dilemmas, the practitioners acknowledged the presence of these dilemmas in their organization. However, they also mentioned to miss some aspects in the framework which influenced

their MR&R challenges. The four aspects related to the completeness of the framework are: including private involvement, interaction with asset managers, impact of political influence and stimulating the realization of certain requirements. The explanations of the several aspects is provided in the paragraphs below:

Firstly, the absence of a private involvement dilemma was mentioned. The Municipality of Amsterdam decided to develop a program and within this program an incredible amount of MR&R related activities are salvaged. An important part of their MR&R related activities is the development of innovations like: new building techniques and condition assessment methods. Current standards and regulations developed by Rijkswaterstaat are used, which in general posses different kind of assets compared to the assets located in Amsterdam. Reason to invest time and effort in for example these condition assessment innovations, resulted from the desire to get a more reliable overview and lower uncertainty regarding the actual state of the assets. Based on these more detailed technical asset conditions, they are trying to plan a significant amount of MR&R interventions in a relatively small area on a longer time frame. To develop those new techniques and innovations, close collaborations with the private sector are necessary. However, the fact that private involvement is necessary during the FED can be seen as a consequence of the decision to have an attitude aiming to reduce uncertainty, as described in the considerations in section 5.5. Adding private involvement to the decision-making framework is therefore considered not to be necessary.

Secondly, the interaction with the asset managers was perceived as an important aspect of the FED process. As the asset managers work with their asset(s) on a daily base, their knowledge could provide detailed information on the necessary MR&R intervention. Creating the opportunity to use their (tacit) knowledge during the FED is however not really a dilemma, but more a consequence of the chosen FED procedure. For example, the integration, interfaces and attitude dilemmas all influence the chosen procedure which may affect the direct involvement of the asset manager. If the scope of the FED is kept small, more detailed data is gathered easier as the distance between the project teams and the assets is smaller as well. The importance of the (tacit) knowledge of the asset managers is undeniable. Therefore, when increasing the scope of the process, involved persons should attribute extra attention to including the asset managers and their knowledge during the FED.

Thirdly, the impact of the political influence was mentioned. The PBK is a direct subordinate of the Alderman of the Municipality of Amsterdam and VenR team WNN operates under the Regional Director, which is a subordinate of the Board of Rijkswaterstaat which is directly linked to the Ministry of Infrastructure and Water Management. Political decisions will therefore have a direct influence on the activities of both teams. Despite the importance to acknowledge this link of both MR&R challenges with the political influence, it is not a dilemma for the developed framework. Reason for this lays in the purpose of the framework, which aims at adjusting the FED process to the present MR&R challenge and requirements. Logically, political orders may change these requirements and the related FED design, but is outside the scope of the framework and the power of the decision-makers in charge.

Lastly, the attendees mentioned the absence of decision-making opportunities to stimulate certain requirements like sustainability, accessibility, mobility and innovations. Instead of mentioning these requirements individually, the decision-making framework consist of the opportunity to express preferences among the desired requirements within the compromise dilemma. Trade-offs on stimulating certain requirements are related to the conditions of a case at a certain point in time, which are part of the compromise dilemma when decided to express preferences.

2 - Functioning

The second objective was related to the intention to check the functioning of the decision-making framework. In chapter 5, every dilemma is supported with an explanation of relevant considerations which should support the decision-making authority in making a decision on the related dilemma. To check whether the considerations and related decisions actually correspond with the reality, they are mirrored to the situations of both organizations. Instead of discussing all considerations separately, the

consequences of made decisions are discussed in a rather general manner. The most striking aspects which resulted from the expert review were: the effect of implementing many changes simultaneously on the organization and the (unforeseen) appeal of being a program, both related to the PBK.

Creation of the PBK was initiated by the the Board of Mayor and Aldermen (Dutch: College van Burgemeester en Wethouders), in order to boost the MR&R challenge the Municipality is facing. A new way of working was determined to be necessary to increase the current speed of MR&R interventions and create additional (strategic) benefits (as shown in A.3). With the strong focus on new and innovative ways of working, a lot of changes to the organizational structure and related procedures were made. Despite the energy of the Program Board and involved directors, they face a reluctant attitude of the employees which have to execute the work. The persons in the teams are sometimes work in a certain way for multiple decades, and now have to change this due to the development of the program. This creates opposition by the employees, as they now have to change their way of working, while they often do not see the added value of this change. Together with this lack of motivation, the ability to execute the necessary work is harder and takes longer. The risk of adjusting the FED process on the motivation of the employees and the execution of FED activities was not identified in the previous chapter. However, it is an important aspect as humans are considered the key to success.

Together with the creation of the PBK, the program caught a lot of attention within the Municipality. Other divisions responsible like for example: Traffic and Public Spaces, see the creation of PBK as an opportunity to execute their projects together with PBK. However, these projects often lack any interface with the initial MR&R interventions. On one side, the program board of PBK also sees the advantage of creating such integrated solutions. On the other side, it increases the scope of the program even more. By being a program, other divisions can find potential interfaces between the PBK and their projects easier as the PBK now operates on a higher stage. The appeal of being a program is however questionable, when it (negatively) influences the development of the initial program and its requirements.

All in all, creation of the PBK made sense as the Board of Mayor and Alderman saw the necessity to intervene in the severe MR&R challenge the Municipality of Amsterdam is facing. By being a MR&R program, all MR&R related activities automatically became the responsibility of the program, and even activities which have noting to do with MR&R in general are trying to seek interfaces with the program. This increased the scope and amount of considerations to such an extent, that the program directors honestly admit that the situation is very complex. To deal with these levels of complexity, new procedures are developed. However, this leads to reluctance of the employees, as they have to change their (standardized) way of working. Altogether, the idea behind the creation of a program and the potential benefits are understandable. Despite, the scope of the FED of PBK is currently that large, that they face difficulties in moving from the FED phase toward the execution phases, as decisions on project configurations are so interrelated.

3 - Usability

The last objective was to validate the usability of the framework. Important aspect of the usability was the question who had the decision-making authority to make these trade-offs and implement the consequences of it. The decision to segmentate the MR&R activities in Amsterdam as a program and to carry out the VenR MR&R projects in the present organizational 'line', was made by the Board of Mayor and Aldermen and Board of Rijkswaterstaat, respectively. The attendees of the event mentioned that they had little to no influence on this decision. Regarding the other dilemma's on both a program-level and an asset-level (as indicated in figure 5.1 were to be made by them, the PBK Program Board and IPM team of Rijkswaterstaat WNN. However, all decisions have to be approved by the serving Alderman or Board. Given the existence of this controlling mechanism, the opportunity to make quick adjustments to the FED process is however limited. Thereby, the attendees acknowledged the importance of the agility dilemmas but pinpointed the necessary time of really adjust previously made decision according to the relatively sluggish administrative processes.

6.2.4 Concluding remarks

Conducting an expert review provided a superb opportunity to validate the developed decision-making framework. Despite the fact that the expert review did not lead to physical adjustments to the framework, useful insights in the functioning and usage were gathered. It can be concluded that the significant complexification of the FED process within the PBK led to severe manageability issues, as the amount of elements and interrelations within the scope of the PBK potentially exceeds the present span of control. Thereby, the amount of related changes to the FED process of the PBK lead to a reluctant attitude with the involved employees, which have to carry out the FED steps. Both aspects function as new input for the considerations within the developed decision-making framework. Thereby, it was confirmed by the attendees that the decision whether to create a separate MR&R division lays with the Board of an organizations (which is embodied the Alderman in the case of a Municipality). The other trade-offs are to be made by the Program Board or management team which is in charge of the MR&R challenge. However, permission and adaption of the to-be made decisions should be approved by the parent authority. Since the aim of the framework is to show the decision-making opportunities for the decision-making authority in charge, it is useful to know that in the end the decision-making authority is always with the Board. However, trade-offs on all dilemmas expect the segmentation are to be made by the executive board related to the MR&R challenge.

6.3 CONCLUSION

To validate and identify potential shortcomings of the developed decision-making framework, the following sub-question is answered:

Sub-question 4 *- "What are the effects of empirical reviews on the performance of the framework?"*

In order to validate the developed decision-making framework, an imitation experiment and an expert review are conducted. The imitation experiment was carried out by providing an answer for the created decision-making framework, based on the conditions of Rijkswaterstaat's VenR challenge in Tranche 4. Based on the outcomes, the trade-offs were translated to a decision-making process (as shown in figure 6.5) which aimed to transform a set of soon-to-be outdated assets in to be executed projects or programs in a fit-for-purpose manner. The decisions were made in a manner that tried to increase the complexity of the FED process to create opportunities for asset transcending benefits, but also limit the complexity to such an extent that the amount of considerations and the related span of control would not be too large to keep the process manageable. This resulted in an overview of multiple configuration options among the 17 bridges within Tranche 4. Given certain preferences, three examples of potential clusters were presented to show the functioning of the FED process and underlying decision-making framework. In contrast to the one-asset-one-project procedure, which was leading in the current FED procedure of VenR, the potential configurations showed additional opportunities to enlarge the solution space and create asset transcending benefits by using the developed framework. However, given the deliberate complexification of the FED process, the amount of interrelations also increased significantly, which complicated the decision-making process sufficiently. Thereby, the imitation experiment did not appoint the presence of various decision-making authorities within one organization, which may have various interests and decision-making power. Therefore, it was decided to make this one of the objectives of the expert review.

In the presence of the PBK Program Board of the Municipality of Amsterdam and the VenR team of Rijkswaterstaat region West Netherlands North, the expert review was conducted. Given the limited time to conduct the expert review, it was decided to limit the objectives to a validation of the: completeness, functioning and usability of the decision-making framework. Despite the conclusion that the decision-making framework itself does not have to be changed, the related consideration were both confirmed and complemented.

Since the Board of Mayor and Aldermen of Amsterdam decided to set up the PBK, in order to deal with the immense MR&R challenge of bridges and quay walls in Amsterdam, the persons who have to

execute the work now face some serious implementation issues. First of all, being a program attracts the attention of other divisions inside the Municipality. Other departments may see the scope and related works of the PBK as an opportunity to propose realization of their own projects which may have a certain relation to the PBK scope. However, all new ideas and potential interfaces with other divisions increases the scope of the decision-making process of PBK sufficiently. Drawing a hard line, based on the interface dilemma, may provide a solution for this kind of complexities. On the other side, organizations may draw attention to the 'naming and framing' of their MR&R challenge, as this logically influences the appeal of a project or program in an organization. An other new finding, was the reluctant attitude of the employees, as a consequence of creating a new division and procedure to boost the MR&R activities. By changing the current FED process to a 'new and innovative' way of working, this conflicts with the standardized way of working of the persons who execute the FED process. Perhaps, it would have been better to limit the scope of the program to the reduction of the amount of deferred maintenance or only MR&R projects. The current scope seems to exceed the abilities of the program and involved persons which hampers the shift from FED to execution of the necessary MR&R interventions.

All in all, the empirical reviews of the developed decision-making framework confirmed the completeness, functioning and usability on one side, and led to some new insights on the other side. Conducting an imitation experiment to more MR&R cases, and reviewing the framework with other public organizations would logically improve the validity to a larger extent.

7 CONCLUSION AND DISCUSSION

This chapter is the 'grand finale' of the research. By reflecting back on the outcomes of the sub-questions in the previous chapters, a comprehensive answer on the main question is to be formulated. After the conclusion, the limitations of this research are discussed. Given the conclusion and related limitations, recommendations for public organizations regarding the implementation of this research will be provided. This chapter ends with recommendations for future research, based on the findings of this research.

7.1 CONCLUSION

With the predicted rise of to-be renewed or replaced assets, public authorities will be dealing this kind of challenge to a greater extent in the coming decades [Nicolai et al., 2016]. Previously, the focus of public organizations within the transportation infrastructure sector was primary on the realization of greenfield projects. Therefore, the growing MR&R challenge is not their cup of tea yet. During the preparatory FED phases of a project, organizations normally determine how they can develop a project on time, in budget and to scope [Edkins et al., 2013]. However, as the amount of assets which demand a MR&R intervention is growing, both the necessity and opportunity to look beyond the borders of a single asset in terms of project development emerges. Research by Platje and Seidel [1993]; Pellegrinelli [1997] pinpoint the benefits of program management to manage the interdependence between multiple projects in a coordinated matter. Therefore, an important aspect of the FED phases of MR&R challenges is the potential to configure such programs or projects out of the totality of assets which are in need of a MR&R intervention in the nearby future.

Figure 7.1: Overview of the black box system visualizing the FED of MR&R projects

Figure 7.1 visualizes the FED of MR&R challenges as a black box. Within the black box, the dynamics which take place during the FED are investigated. To create insights in the (unique) complexities of MR&R challenges and opportunities to deal with it, the purpose of this research was to open up the black box and answer the following research question:

"How can decision-making on the MR&R interventions of the emerging set of soon-to-be outdated assets be supported to configure assets in a fit-for-purpose manner?"

Yet, both scientific literature and empirical experience on the ways to design the FED to create such fit-for-purpose projects is rather limited. Fit-for-purpose, in this sense, refers to the ability of a project to solve the problem best, given the other alternatives [Koops et al., 2017]. The FED process is seen as the procedure to transform unstructured MR&R challenges in fit-for-purpose and executable projects

[Smith and Winter, 2010] Therefore, this research is particularly focused on the FED phase of such MR&R challenges.

To compose an answer on the main research question, a first appeal was made to the present body of scientific literature. The objective of the first sub question was to identify which aspects influence the decision-making process related the configuration of these MR&R projects. It was found that their is no uniform way to make decisions on the configuration of MR&R projects. Instead, a playing field of **requirements, asset conditions, design alternatives, resources and configuration options** determine the content of the decision-making process. Thereby, the FED process itself may differ in **composition, scope and sequence** of the decision-making moments. Yet, the way these aspects relate to each other required further investigation.

Jointly, the aspects created a conceptual framework by which multiple MR&R cases were analyzed. In line with the second research question, the aim was to gather empirical insights in the complexities of MR&R challenges and the potential ways to deal with it. The empirical data was analyzed by conducting both an individual case analysis and a comparative case analysis of four MR&R cases. A selection of two Rijkswaterstaat cases, together with one case of the Municipality of Amsterdam and one of the Province of North-Holland was made. By analyzing four different cases of three public organizations, a comprehensive view on the challenges in Dutch MR&R challenges was developed. Next to the consultation of project related documentation, exploratory interviews with the involved staff are held to gather an enhanced view on the challenges, made decisions, rationale behind these decisions and the related consequences of these decisions. Based on these insights and the related analysis, the earlier mentioned conceptual framework was extended to an overview of complexities as presented in table 7.1.

	Complexities	**No.**	**Description**
Content	Requirements	1	Influence of organizational strategy
		2	Amount of requirements
		3	Conflicting requirements
	Asset conditions	4	Detail of condition assessments
		5	Need of certain expertise
	Resource allocation	6	Composition of teams
		7	Financial flexibility
	Design alternatives	8	Varying impact of design alternatives
	Configuration methods	9	Diversity of configuration grounds
		10	Variety of configuration options
		11	Necessary effort to find configurations
Process	Composition	12	Consciously including or excluding elements
		13	Using a stage-gate system
	Scope	14	Increased scope leads to more interrelations
	Sequence	15	Premature convergence leading to path dependency
		16	Options to postpone crucial activities
	Coordination	17	Creation of a program
		18	Including VenR in the regular workflow
	Adaptivity	19	Introducing GBC in a phased manner
		20	Revising the FED process for a new Tranche

Table 7.1: Overview of the present complexities during the FED of MR&R projects

These complexities presented the hurdles which influence the decision-making process during the FED phase of several MR&R challenges. The complexities are divided in both content-related complexities and process-related complexities. Content, in this sense, refers to the grounds where decisions regarding the configuration of MR&R challenges are based on. For example, the need for certain expertise regarding the determination of the MR&R interventions may influence the decisions whether to merge certain assets into a project or program. On the other side, process-related complexity refers to the potential ways the FED procedure can be designed. The decision to postpone detailed condition assessments to a moment after the FED process may create opportunities to merge certain assets into a

project or program on different grounds.

After identification of the present complexities in various MR&R cases, the second part of the research was focused on finding ways to deal with this challenges. Based on the identified twenty complexities, seven decision-making dilemmas were distilled which show the opportunities public organizations have in designing their FED process. By identification of these dilemmas, the research aims to reveal how public organizations can deal with their MR&R challenges and the set-up of their FED process. The design of the FED process shows the way 'MR&R-needy' assets are transformed into projects or programs which are ready for execution. Despite the fact that public organizations all designed their FED process differently, the composed trade-off which determine the design of the FED process showed certain similarities.

These dilemmas jointly determine the available space to seek potential configurations beyond the borders of a single asset. Thinkable opportunities of this approach are the potential to implement strategic objectives, create chances for economies of scale and optimize resource allocation, reduce the amount of procurement processes, improved alignment with other projects and opportunities to efficiently store and share knowledge over projects, by merging multiple assets into one enclosed environment [Gray, 1997; Pellegrinelli, 2002; Boes and Dorée, 2008; van Buuren et al., 2010]. On the other side, expanding the scope from one to multiple assets during these early project phases also imposes certain threats, as the amount of involved components and actors requires a greater span of control [Leijten, 2017]. If the complexity outreaches the span of control of the appointed management organization, manageability issues may apply which hamper the development of the project or program [Heeres et al., 2016]. Possibilities to seize the present opportunities and deal with the potential threats of MR&R challenges in a fit-for purpose manner, are salvaged in the following trade-offs:

1. **Segmentation:** Create a new division in the organization to deal with all MR&R projects or embed the MR&R projects in the existing structure and procedures
2. **Integration:** Focus the FED process on all assets separately, or seek integrated solutions for multiple assets simultaneously
3. **Interfaces:** Keep the focus of the FED process on the MR&R projects or seek interfaces with the development of non-MR&R projects
4. **Compromise:** Seek overall consensus on the present set of requirements or attribute relative preferences
5. **Attitude:** Focus the FED process on reducing the uncertainty or accept the present levels of uncertainty
6. **Expectations:** Focus on the improvement of the technical life span of an asset or include room to seek new functionalities
7. **Agility:** Stick to made decisions during the FED process, or include opportunities to review and revise made decisions

Altogether, these decisions on the dilemmas are a trade-off between a simplification or a complexification of the FED process. Between the identified dilemmas certain interrelations exist, as one trade-off has (in)direct consequences on other trade-offs. These interrelations are emphasized by the categorization of two clusters. The first cluster indicates the context of the FED process, which is composed of the segmentation, interfaces, expectations and agility dilemmas. Together, these dilemmas set the boundaries of the physical aspects which are included in the decision-making process. The second cluster determines the followed procedure during the FED process, and is shaped by the integration, compromise, attitude and agility dilemmas. Merging the two clusters led to the decision-making framework (as presented in figure 7.2, which thereby fulfills the third research objective.

By using this framework, public organizations can be supported in the decision-making procedure which leads to a FED process design. Based on the present characteristics of the specific MR&R challenge, public organization may determine if and how the FED can be adjusted to find fit-for-purpose

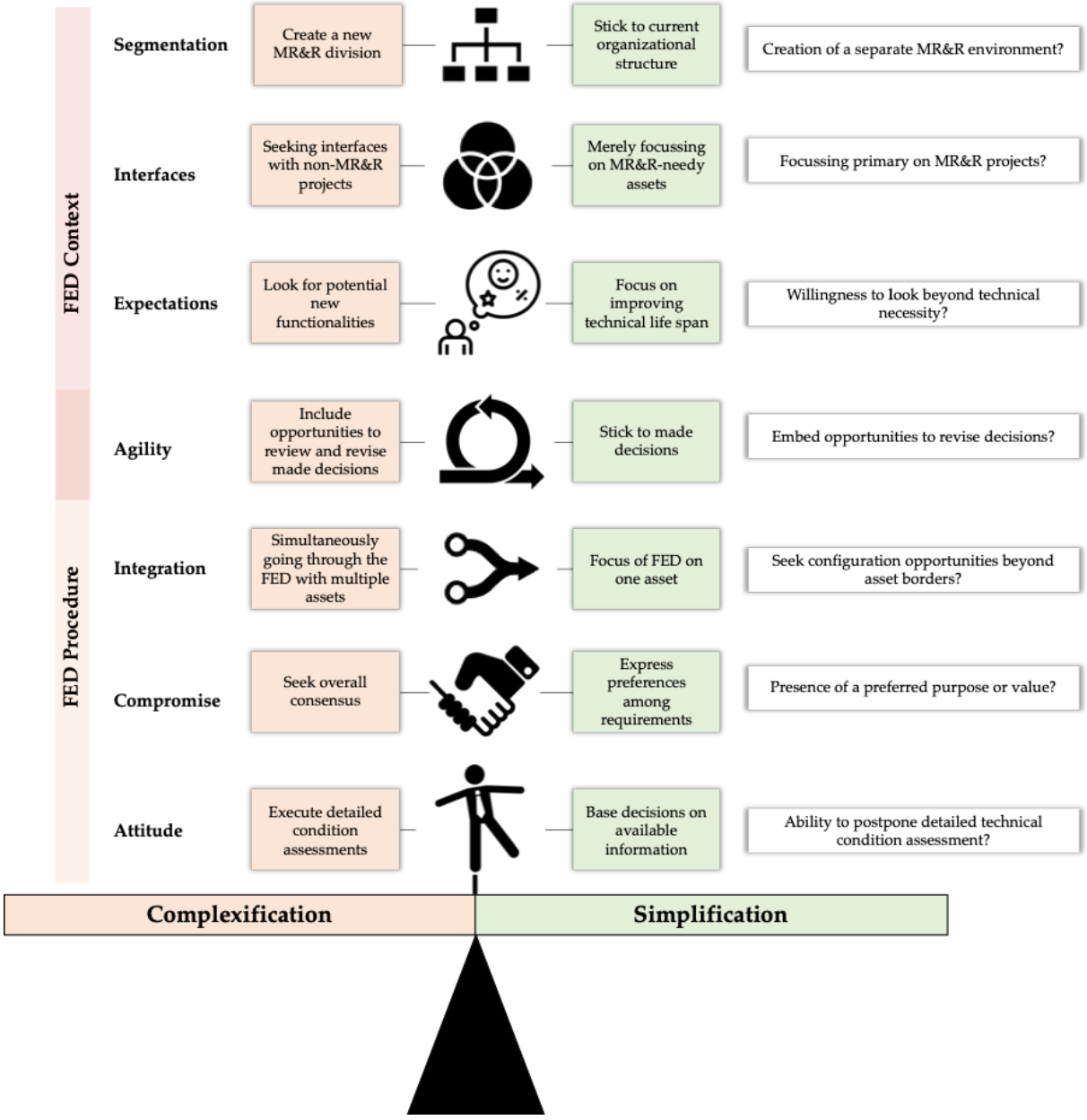


Figure 7.2: Overview of the decision-making framework

configurations. As a consequence of acknowledging and using these seven identified trade-offs, organizations can align their FED procedure to the desired outcomes of this process.

As shown in figure 7.2, the trade-offs consist of two options to either simplify or complicate the FED procedure. Choosing for simplification will keep the FED procedure clear and fairly simple, which may be preferable given certain circumstances. For example, a situation which demands quick decision-making due to the poor condition of an asset. On the other side, deliberate complexification may increase the to-be considered elements and interrelations during the FED process, but therewith increases the opportunity to find solutions which would otherwise not emerge. Since the developed decision-making framework embodies seven opportunities to align the FED procedure with the desired outcomes of the process, a huge variety of potential FED process designs is created. While having the opportunity to both simplify and complicate the FED process in numerous ways, a balance is intended to be found. Choosing for complete simplification or complexification will probably lead to overlooked opportunities or unmanageable configuration processes, respectively. With the help of this framework, public organization may be guided in the potential ways deal to with the FED process of their MR&R chal-

lenge.

Despite the created framework is based on both scientific literature and empirical data, the fourth research objective was intended to validate the decision-making framework. Therefore, it is tested and reviewed by conducting an imitation experiment and an expert review session. The objective of the imitation experiment was to show how the trade-offs can be made and what the consequences of these decisions are on the FED process design and the related outcomes of the configuration process. Based on the characteristics of an existing case: the 'Vervanging en Renovatie Opgave' Tranche 4 of Rijkswaterstaat, the imitation experiment was executed. Given the characteristics of the case, made and explained trade-offs eventually led to a FED process design which aimed to balance the complexity of the FED while simultaneously creating sufficient opportunities to create asset transcending benefits. In the end, the imitation experiment led to the confirmation that the developed framework creates the opportunity for public organizations to align their FED process to the creation of desired outcomes. Several potential multi-asset projects within Tranche 4 of the VenR challenge were created, based on various grounds.

However, the imitation experiment was executed in somehow unrealistic conditions, neglecting for example the presence of different decision-making authorities within one organization. To further validate the developed framework, practitioners of Rijkswaterstaat and the Municipality of Amsterdam were asked to shed their light on the developed framework. The objective of the expert review sessions was to verify the completeness, functioning and usability of the framework. During the expert review session, the completeness of the developed framework was confirmed by the attendees, since they acknowledged the presence of such trade-offs regarding the design of the FED process of their MR&R challenge. Additionally, the functionality was extended with two major aspects. First, the reluctant attitude of employees when their current and comfortable way of working is changed due to the development of a new program. Next, the attraction by other organizational divisions to see the creation of a new program as an opportunity to realize joint projects. Regarding the usability of the framework, the attendees mentioned that the decision related to the segmentation dilemma was made by the present Board or political superior of the organization. The remaining six trade-offs could be made by the program or managing board in charge of the MR&R challenge, but always need permission of the serving superior authority. Altogether, the expert validation session, in combination with the imitation experiment contributed to the validity and usability of the developed decision-making framework for practitioners in future MR&R challenges.

To conclude the research and provide an answer on the main question, decision-making on the emerging set of soon-to-be outdated assets could be supported to configure assets in a fit-for-purpose manner by using the developed decision-making framework and consulting the discussed considerations related to these trade-offs. The framework is usable for the Board, Minister, Provincial Council or Board of Mayor and Aldermen in charge, to make decisions on the design of the FED process to deal with their MR&R challenge. By having an overview of the playing field of related dilemmas on all institutional levels within an organization, decisions can be aligned in order to make sure the MR&R challenge is transformed into to-be executed projects or programs in a fit-for-purpose manner. Consequences of deliberate simplification or complexification of the process needs to be observed from an integrated perspective, as the decisions have a certain interrelatedness with each other. In the end, it is about finding a balance between the present requirements, complexities and resources to develop a process which creates sufficient opportunities for asset transcending benefits on one side, and a FED process which is manageable for the involved staff on the other side. By having seven separate opportunities align the FED procedure and the desired outcomes of this process, public organizations have a multiple opportunities to realize their objectives in a fit-for-purpose manner.

7.2 DISCUSSION

Since large-scale MR&R challenges are relatively new for the Dutch transportation infrastructure sector and the amount of (scientific) research on this topic is limited, this research functioned as an exploratory research into the complexities and ways to deal with these complexities during the FED phase. As the scope of this graduation research project was bounded to a certain time-frame, the research is

prone to some limitations which will be discussed in subsection 7.2.1. Considering the limitations, recommendations for future MR&R challenges will be discussed in subsection 7.2.3. As last part of this discussion, the recommendations for future research will be elaborated in subsection 7.2.4.

7.2.1 Limitations of the research

In addition to the conclusion of this research, the research was also bounded by some limitations:

Firstly, the conclusions of this research are supported by a comparative case analysis which focused on four different MR&R cases. By having insights of cases with a different purpose, budget and conditions, a broad overview of the complexities during the FED of MR&R challenges was intended to be created. However, as the Netherlands consist of a wide diversity of public organizations which operate in the transportation infrastructure sector, execution of the same analysis in a different case would not naturally lead the same outcomes. Therefore, the developed framework can be considered as a non-exhaustive overview of opportunities public organizations have while dealing with their MR&R challenge.

Secondly, the dilemmas which are presented in the decision-making framework show two opposite choices on a certain topic. Yet, the presented decisions which are related to a certain trade-off are a reflection of the observations made in the comparative case analysis. In line with the previous limitation, the two mutually exclusive choices within an identified dilemma, may in other cases potentially differ since the analysis was based on four MR&R challenges of three different public organizations.

Thirdly, the conducted expert review was limited to an attributed time-frame, given the planning of the knowledge sharing event between the Municipality of Amsterdam and Rijkswaterstaat. Therefore, the completeness, functioning and usability of the framework is validated to a limited extent. On the other side, the fact that the attendees admitted the importance and presence of the trade-offs in their daily work with MR&R challenges, also indicated the added value of the developed decision-making framework. Conducting more expert reviews with other attendees from other public organizations would however increase the validity of the framework to a greater extent.

Fourthly, the developed decision-making framework provides an overview of the dilemmas which occur during the FED in a rather generic way. On an execution level, every case will face unique and detailed challenges which the framework cannot answer. Despite this was not the purpose of the research and the developed decision-making framework, it is worth mentioning as readers might misunderstand the contribution of the research.

7.2.2 Relevance of the study

In the light of the discussed social, scientific and and project relevance in section 1.2, a final explanation of the contribution to these aspects based on the conducted research will be discussed.

Social relevance

Being the client comes with the responsibility to safeguard public values in infrastructure development. As observed throughout the research, the presence of various values however creates a situations which demand trade-offs to be made. Like observed in the Program Bridges and Quay Walls of the Municipality of Amsterdam, the execution of the MR&R interventions goes hand in hand with deliberations affecting safety of the surroundings and users, nuisance to the environment and expenses both on short and long term. In order to support public organizations, this research created a distinction in several requirements as discussed in subsection 4.1.1.

By categorizing the present requirements of a MR&R challenge accordingly, the developed framework and in particular the compromise dilemma revealed the opportunity for the public authority in charge to value certain requirements more important than others. Making a decision to create a distinction among the requirements, creates the opportunity for public organizations to stimulate the realization

of a certain value. Since the developed decision-making framework may be adopted to design the FED process in a fit-for-purpose manner, using the framework can lead to a guided fulfilment of the intended values during the execution of the MR&R interventions. Therefore, the outcomes of the analysis and the developed framework can support the decision-making process by making substantiated trade-offs which in the end are intended to optimize the realization of public values.

Scientific relevance

In contrast to greenfield projects realizing new pieces of the infrastructure network, MR&R challenges are focused on the conservation of the existing infrastructure. Since the magnitude of MR&R projects was relatively low in the past, both scientific literature and practical experience has been relatively limited on this topic. As multiple public organizations in the Netherlands are currently facing larger MR&R challenges which comprise a larger share of the entire portfolio of projects, the necessity to contribute to this underexposed research field became clear.

This study contributed to the present body of scientific literature in various ways. Since the FED phase is widely respected as an important stage in the project life cycle to lay grounds for future project success, the research primary focused on this phase. However, the options on how to carry out an appropriate FED in the light of a MR&R challenge are underexposed in literature. In addition to papers of [Šelih et al., 2008; Nielsen et al., 2016], which describe the activities (during the FED phase) which go on before the actual MR&R projects are designed, planned and executed, this researched showed the possibilities on how to actually design this process. In contrast to the previously mentioned papers, it was found that the activities which are carried out during the FED are actually influenced by a broad set of aspects i.e. complexities. The conducted comparative case analysis therefore showed and categorized present complexities which occur during the FED phase of MR&R challenges. These complexities highlighted in which sense decision-making during the FED regarding the future development of a set of soon-to-be outdated asset is influenced, which is summarized in table 7.1.

Next to the identification of complexities which determine how MR&R challenges of public organizations are tackled, the second part of this research indicated how problem owners may deal with these challenges and design their FED process accordingly. Given the magnitude of the present MR&R challenges, often consisting of significant amounts of soon-to-be outdated assets, the opportunity carry out the FED for multiple assets at the same time was investigated. Based on a combination of the present body of knowledge on portfolio and program management and the observed FED processes of the MR&R cases, a decision-making framework (as presented in figure 7.2) is developed. This decision-making framework shows seven different key dilemmas which jointly result in a design of the FED process, based on the present requirements, characteristics and related complexities of a MR&R challenge. By creating this framework, the present body of knowledge on portfolio and program management is extended with a tool to align the present MR&R challenge to a FED process. Instead of making a "blunt" decision whether to manage a MR&R challenge in a portfolio-based or program-based, seven deliberate trade-offs are indicated which unitedly design the FED procedure.

Therewith, the present body of knowledge on stage-gate systems, MR&R interventions and related activities (inspections, condition assessments, risk assessments etc.) which may be part of the FED of MR&R challenges are included to the decision-making framework. This makes the framework especially usable for (public) organizations which face MR&R challenges. However, next to the initial purpose to develop a framework for public organizations which face MR&R challenges in the public transportation sector, the framework is more versatile. Any organization which faces a challenge where multiple assets need to be maintained, renewed or replaced can benefit from using the framework while designing their FED procedure. Therefore, the scientific value is not limited to MR&R challenges within the transportation infrastructure body of research, but to a wider spectrum of MR&R challenges. An airline operator for example, which faces a MR&R challenge due to the deterioration of their fleet may use the framework as well. Same as bridges or tunnels, airline operators deal with a variety of airplanes. The indicated trade-offs, related to the segmentation, interfaces, expectations, agility, integration, compromise and attitude therefore also play a role while determining a fit-for-purpose FED design in other research fields, next to the transportation infrastructure.

Project relevance

While being the motive of this research, the 'Vervanging en Renovatie Opgave' of Rijkswaterstaat can benefit from the outcomes of this research by acknowledging and using the developed framework for future Tranches. Since the analysis existed of a comparison of multiple MR&R cases inside and outside Rijkswaterstaat, the current way of working is challenged on several criteria. Based on the shared insides of the theoretical background and empirical knowledge, the decision-making framework was developed. By using the framework, Rijkswaterstaat and other public organizations may make deliberate trade-offs regarding the layout of their FED procedure. By having such a large-scale and diverse MR&R challenge, the opportunities to merge multiple assets into one project, portfolio or program are endless. Based on the dilemmas in the framework and the related considerations, Rijkswaterstaat can make guided decisions on the design of their FED process for the upcoming Tranches. Despite the fact that the trade-offs are probably not completely new for Rijkswaterstaat, having them all in one overview including explanations of the potential consequences creates added value in aligning their FED to their MR&R challenge. In the end, using the framework should lead to improved outcomes like: optimized resource allocation, guided realization of preferred (public) values and opportunities to realize tactical and strategic benefits.

7.2.3 Recommendations for public organizations facing MR&R challenges

Using the developed framework and the related consideration would be a valuable starting point for public organizations which face a MR&R challenge. By having an overview of the decision-making opportunities and the potential consequences of certain decisions, the organizations can align their FED process with the intended benefits and present requirements. A detailed explanation on how to use the developed framework is provided in Appendix F

However, the usability of the framework is also dependent on the circumstances an organization is currently facing. During the expert review session, the consequences of changing an existing procedure came to light. If the staff within an organization is used to a certain procedure, the earlier mentioned standardization benefits should not be underestimated. Changing these procedures can result in a reluctant attitude of the employees, which negatively influences the progress of the FED process. Changing the organizational structure and related procedures overnight to tackle a MR&R challenge is therefore not necessarily the best solution. Mirroring the trade-offs in the framework to the current situation within an organization, should shed light on the current circumstances and potential adjustments as a consequence of certain decisions.

Important consideration related to the segmentation and interface dilemma, is the 'naming and framing' of an MR&R challenge, Sometimes, organizations execute their MR&R projects already for a long time, without putting a label on it. Once a program is developed, like in the Municipality of Amsterdam, a lot of attention is caught by the program. Rijkswaterstaat for example, calls their MR&R challenge: "The greatest MR&R challenge in the history of the Netherlands". This attracts the attention of other departments within the organization, which sometimes seek interfaces to collaboratively develop projects with no or limited connection to the existing MR&R scope of projects within the program. Perhaps it could be beneficial for the progress of the FED process to deliberately consider the positioning of the MR&R challenges within the organization as every potential interrelation further complicates the decision-making process.

7.2.4 Recommendations for future research

While this research was mainly focused on investigating the present complexities and finding potential ways to deal with these challenges and opportunities through decision-making during the FED, future research may focus on the achievement of these opportunities. This would imply a more detailed focus on the configuration process which takes place during the FED. The opportunities to realize the benefits of asset transcending configurations like: realization of strategic benefits, economies of scale, alignment with other projects and sharing knowledge over project, could be investigated in more detail.

By investigating what kind of configuration suits the achievement of a desired outcome, the FED and the related configuration process may be analyzed in more detail. This may lead to a successor or more detailed version of the developed decision-making framework, which was mainly focus on shaping the environment to find potential asset transcending configurations.

Thereby, this research was mainly focused on the FED phases of MR&R challenges. Opportunities to influence the solution space to find potential configuration are identified by means of the developed framework. However, creating opportunities to seek fit-for-purpose configuration is one. The consequences of these decisions on the success of the developed project or program is also dependent on the consecutive procurement, design and execution phases is second. Therefore, it would be useful to map the consequences of certain decisions during the FED phase, in order to contribute to the stated considerations related to the dilemmas. An ex-post review of the MR&R interventions based on outcomes of the made decisions regarding the design of the FED could provide new insights in the consequences of the made decisions. Therefore, the decision-making framework should be tested in several MR&R environments to provide conclusions on the functionality and usefulness.

As already mentioned in the limitations paragraph, the research consisted of four different MR&R cases of three public organizations in the Netherlands. Extending the analysis with more cases of different public organizations may lead to new insights. Based on these insights, the overview of the complexities and the related decision-making framework may be updated and potentially revised. The validity of the developed decision-making framework will further increase as the amount of analysed cases grows as well. As the validity further increases, the chance that public organizations operating in the transportation infrastructure sector will use the developed framework in order to design their FED will probably increase as well. Based on the stated benefits of using the framework, aligning the present requirements and challenges with the FED process will lead to sufficient performance improvements for the public organization in charge.

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A ADDITIONAL CASE INFORMATION

Within this Appendix, all of the four investigated cases are analyzed in a detailed manner to get a comprehensive view on the present complexities and ways to deal with their MR&R challenge. The four cases are the 'Vervanging en Renovatie Opgave' and 'Kunstwerken Amsterdam Rijnkanaal Groot Onderhoud' of Rijkswaterstaat, 'Programma Bruggen en Kademuren' of the Municipality of Amsterdam and the 'Provinciaal Meerjarenprogramma Onderhoud' of the Province of North-Holland. By having a diverse set of cases with various clients which all have their specific challenges, a comprehensive overview of the complexities which play a role during the configuration of MR&R projects is created. Naturally, the insights of these cases does not create an all-embracing overview of the FED challenges of all public authorities, as differences between different actors and their MR&R challenges simply exists. Therefore, respecting the differences between the different cases plays an important role in the creation of an overview of the complexities of MR&R challenges which are developed in chapter 4.

A.1 CASE 1 – VERVANGING EN RENOVATIE OPGAVE (VENR) – RIJKSWATERSTAAT

The first case is about the Vervanging en Renovatie Opgave of Rijkswaterstaat, which is a nation-wide MR&R challenge which embodies the organizational challenge regarding the aging of their entire set of assets.

A.1.1 Project details

Purpose and project definition

Millions of users use the Dutch highways, waterways and water systems on a daily base. Rijkswaterstaat, which is responsible for the design, construction, management and maintenance of the main Dutch infrastructure facilities, has to find a way to deal with the vast amount of simultaneously aging infrastructure. As it became evident that the amount of assets which need a MR&R intervention will only increase in the nearby future, Rijkswaterstaat has set up VenR. The coming years, Rijkswaterstaat is renewing and replacing over 1000 bridges, locks, tunnels and viaducts. This makes VenR the largest MR&R challenges ever in the history of Rijkswaterstaat. Given the enormity of the task, Rijkswaterstaat developed a list of objectives to carry out the challenge in a fit-for-purpose manner [Rijkswaterstaat, 2019c]:

- Operating safe - Guaranteeing safety (in the broadest sense of the concept) during MR&R activities
- Upgrading the asset state to the technical quality requirements - Working towards a 95% coverage of the assets in terms of technical quality assurance
- Reducing nuisance during MR&R activities - Limiting Vehicle Loss Hours (Dutch: VVU) to have minimal unavailability of current transportation network
- Optimal collaboration with the market (e.g. private parties) – Stimulate integrality by creating an attractive business opportunity for optimal collaboration
- Improving co-operation with the serving Ministry - Aligning approval process by competent authorities with existing challenge to act appropriately
- Improving external and internal communication - Providing effective external communication regarding nuisance and intern communication of related activities

- Align organizational structure with present MR&R challenge - Embedding the (new) MR&R works in the existing organizational structure (alignment of different divisions in new project entity) and improving co-operation between existing organizational divisions and MR&R project team
- Seeking links between MR&R works and other internal projects - Linking MR&R works with other plans within the organizations (newly built projects / new spatial development plans)
- Improving co-operation with local stakeholders - Linking MR&R works with plans of municipalities or other stakeholders operating in the same area and creation of commitment among these stakeholders
- Improving effectiveness and efficiency of project working procedures - Simplification, innovation and optimisation of the FED to switch faster from initiation to execution with less nuisance
- Minimizing negative impact of MR&R activities - Linking MR&R works with plans of municipalities or other stakeholders operating in the same area and creation of commitment among these stakeholders
- Flexibility – Having the opportunity to adapt the asset to future demands, rules and regulations
- Stimulating, developing and implementing innovations – Providing space to develop new technologies, processes and concepts
- Updated information provision of the objects – Gathering accurate information about the conditions of all assets to create a better overview of the total MR&R challenge and improve the predictability of necessary maintenance
- Develop a sustainable living environment – Decision in line with local, regional and (inter)national ambitions, reducing environmental impact and operating circular
- Knowledge building throughout the challenge – Providing the opportunity to apply lessons learned on future projects for all involved parties
- Cost optimization – VenR does not have an infinite budget, which makes trade-offs important

Obviously, the stated objectives of VenR are rather generic. This makes sense, as VenR consist of a wide variation of assets in different conditions all across the Netherlands. Important aspect is the relevance of both tangible as intangible outcomes. Rijkswaterstaat wants next to a safe and sound VenR process, also to limit the negative consequences to for example traffic flows all across the country. Another important feature of the requirements is the improvement of organizational processes. Aspects like knowledge building, improving the effectiveness and efficiency of working procedures, improving co-operation with the serving Ministry and also with private parties indicate the importance of these requirements which are not directly related to the execution of MR&R works. Interviewee RI3 mentioned that the share of VenR-related projects within Rijkswaterstaat is growing and is expected to increase further in the future. Optimization of working procedures are therefore considered to be necessary, to deal with these MR&R projects in a standardized way. Next to the current procedures which currently exist for greenfield projects and large-scale maintenance contracts, VenR must and will become a new and permanent stream of projects within Rijkswaterstaat.

Project facts and figures

VenR was brought to life to challenge the emerging challenge of soon-to-be outdated assets. Rijkswaterstaat is responsible for the the Main Roads Network, Main Waterway Network and Main Water Systems (respectively: HWN, HVWN, HWS). As VenR has no strict project, portfolio or program structure and is seen as an organizational-wide challenge, it has no fixed scope. At the time of this research (early 2020), the VenR has been separated in four tranches which were separated based on the determined urgency of action. Besides the diversity of civil structures, the objects are located all over the country, part of a range of high and waterways, are in a different condition, made out of a wide variety of materials and having a different function. which can be seen in table A.1 and Appendix D.

	Tranche 1-3	Tranche 4
Budget	€1.5 bn.	€1.5 bn.
Planning	2018-2028	2020-2026
Projects	40	40
Bridges	13	17
Road surfaces	2	4
Tunnels	3	10
Viaducts	5	1
Asset controls	2	8
Noise barriers	1	2
Deltas	4	0
Locks	2	6
Stows	1	0
Sheet piles	1	1
Culvert	0	1
Ferry port	0	1

Table A.1: Overview of the VenR projects

For Tranche 1 until 3, the related MR&R activities have already been decided and even some assets have already been either been renewed or replaced. Currently, Tranche 4 consists of 40 projects related to the soon-to-be outdated bridges, tunnels, locks, culverts and sheet pilings, is lacking a fixed plan of action. It can therefore be concluded that Tranche 4 is in the FED phase. Coming up with a configuration on how to set up this replacement and renewal challenge is therefore not straightforward. Altogether, the variety of functions, locations, materials and state of these civil structures form the complexity of the VenR from a technical perspective.

MR&R elements

One of the main challenges of VenR, which is also present in the previously mentioned list of requirements, is the determination of the state of the assets. [Rijkswaterstaat, 2019c]. Determination whether an asset is going to be maintained, renewed or replaced is dependent on the outcome of the developed VenR process, which will be exhaustively discussed in subsection A.1.2.

Finance

Given the size of VenR, the amount of assets which need to be renewed and replaced, results in enormous budgets reservations to carry out the related numbers of necessary preparations and execution of MR&R works [Rijkswaterstaat, 2019a]. For the coming period, until 2050, Rijkswaterstaat makes forecasting analysis to get a statistical insight in the future MR&R challenges. Based on these prognosis, budget reservations for the coming years are proposed to the corresponding Ministry of Infrastructure and Water Management and checked by the House of Representatives. An overview of the actual financial situation is presented in table A.2.

	HWN	HVWN	HWS
Available budget until 2030	3.202	1.300	1.167
Granted to Rijkswaterstaat	1.218	570	175
Reservation Policy Directorate Generals	1.984	830	993
Budget tension Tranche 1-4	-198	-25	-6
Forecast upcoming projects Tranche 1-4	-1.060	-627	-57
Remaining budget for new projects until 2030	742	181	929

Table A.2: Financial overview of VenR of 01/09/2019 (all numbers are in mln. euro)

The budget for VenR is divided into a part that is granted to Rijkswaterstaat and a part that is reserved by the Policy Directorate Generals of the Ministry. Some tensions for Tranche 1-4 apply, as changes led to an increased demand of budget. Next to the existing forecast, the current available budget for HWN, HVWN and HWS in 2019 is €742 million. However, next to the actual present budget, the forecasts

	HWN			HVWN			HWS		
Phase	*Plan*	*Execute*	*Done*	*Plan*	*Execute*	*Done*	*Plan*	*Execute*	*Done*
Tr. 1	0	3	8	2	0	10	1	2	0
Tr. 2	2	3	0	1	1	0	0	0	0
Tr. 3	5	4	0	6	5	0	0	0	0
Tr. 4	19	0	0	19	0	0	3	0	0
+	**26**	**10**	**8**	**28**	**6**	**10**	**4**	**2**	**0**

Table A.3: Progress of VenR project per network

in figure A.1 shows the present budget needs significant additions to cover upcoming VenR expenses. This increase is line with the predictions of Nicolai et al. [2016] in figure 2.1b.

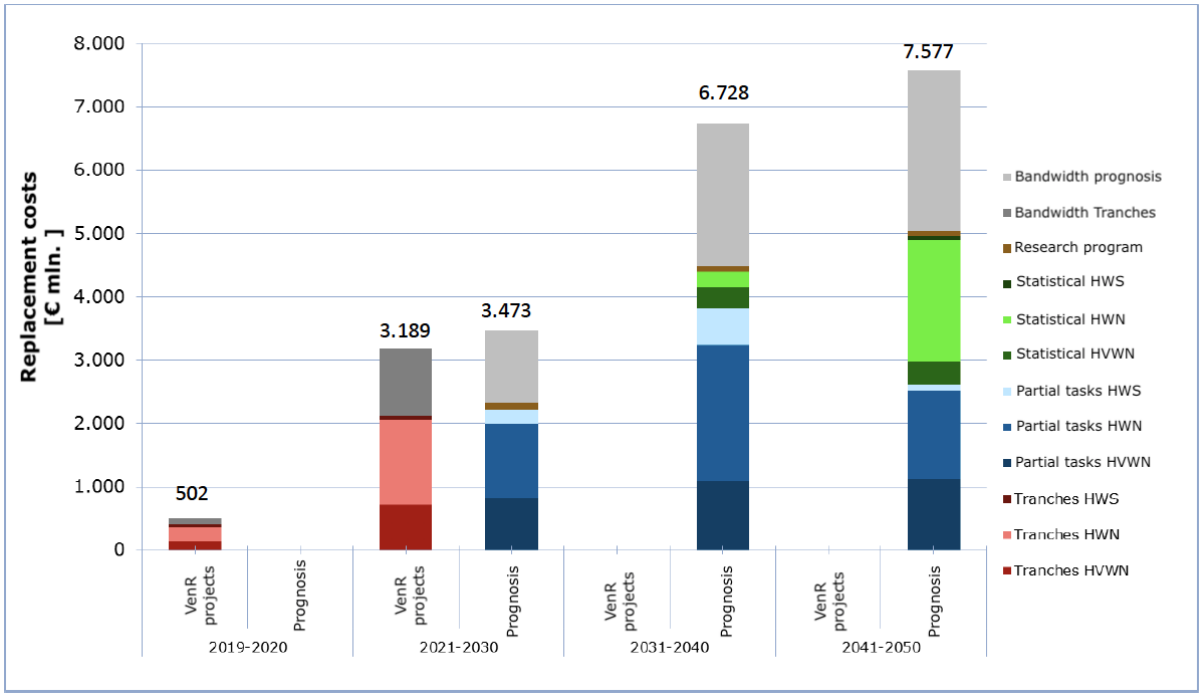

Figure A.1: Total MR&R costs for VenR per period

The (future) expenses of VenR are divided in the earlier mentioned networks (HWN, HVWN and HWS). In red, the allocated budgets for Tranche 1-4 regarding the planning and execution phases. The blue and green bars present the forecast for 2020-2050 per decade. These forecasts are based on the experiences with the first four Tranches and the expected remaining life-span of assets (including taxes). Both bars have a bandwidth of 50% is included, given the present uncertainties. The incorporated uncertainties are related to the: cost price, amount of MR&R needy assets, decisions for the MR&R intervention, inaccuracy of the remaining lifetime forecasts, costs of chromium-6 removal, potential costs of cyber security [Rijkswaterstaat, 2019a]. Important note is made on the qualitative grounds for the determination of a 50% bandwidth, as it is too soon to apply quantitatively substantiated bandwidth calculations.

Planning

While VenR is currently ongoing, an overview of the progress is provided in table A.3.
Analysis of forecasting reports, bi-annual reports and policy documents Rijkswaterstaat [2019c,a,d] show difficulties in the development of some projects, related to several complexities. Within projects among all Tranches, scope changes occur due to unexpected conditions regarding the actual state of assets. Thereby, tuning of projects with other VenR projects or projects which are not inside VenR seem to result in difficulties regarding a necessary lock-down of the scope to continue to the final decision-making moment. Further elaboration on these issues are provided in subsection A.1.2.

Organization

Rijkswaterstaat is the Directorate General for Public Works and Water Management, and is parts of the Ministry of Infrastructure and Water Management. In general, the role of Rijkswaterstaat is the execution of public works and water management. Therefore, it is a real executive organization of the Ministry and often referred to as a project organization, working from one project to an other. Her duties are performed in both national and regional divisions, as presented in figure A.2. Every national organization is responsible for certain types of projects, whereas regional divisions are limited to geographic boundaries. However, all national divisions work together with regional divisions, and vice versa.

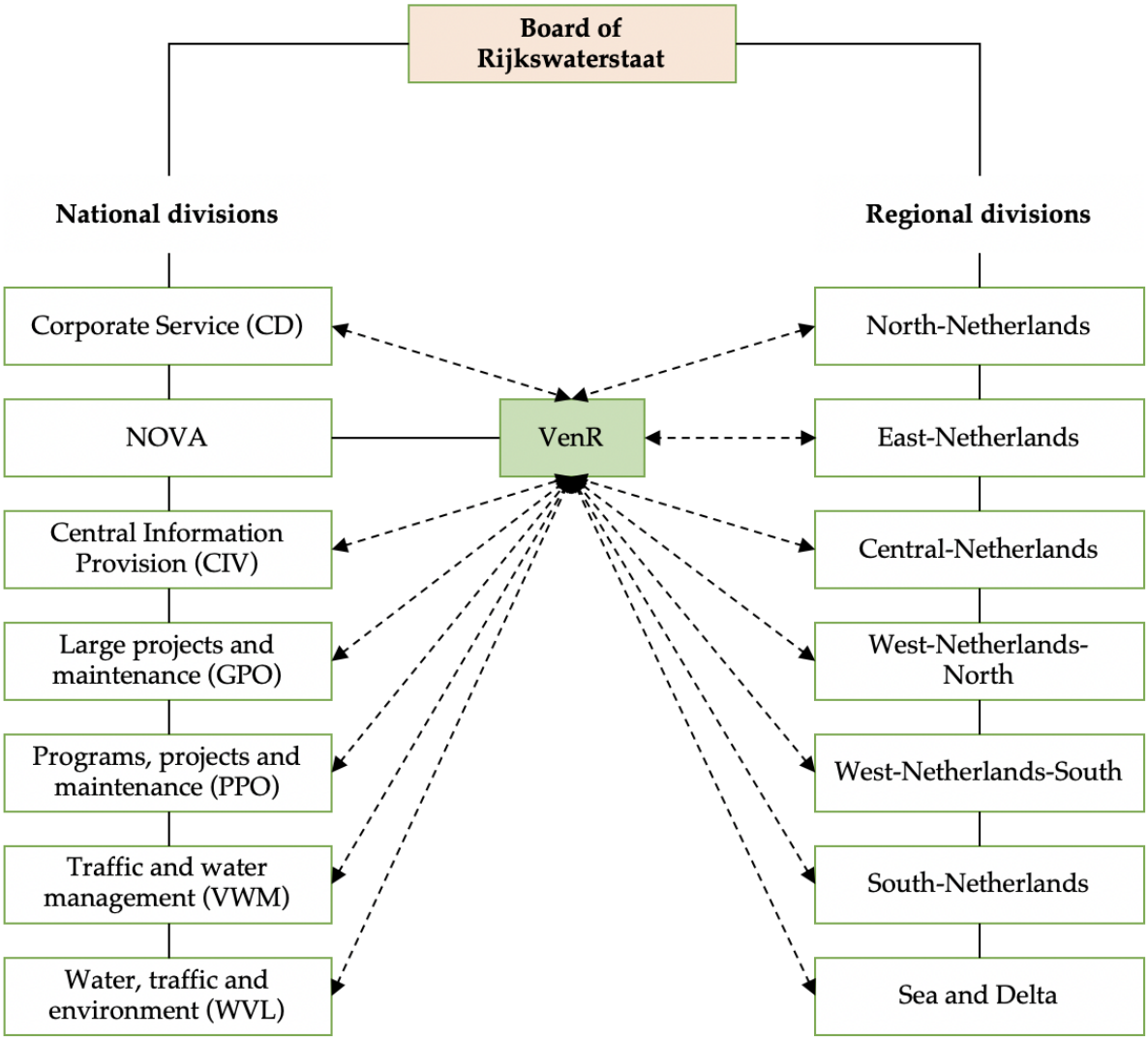

Figure A.2: Organizational overview of Rijkswaterstaat

VenR has a relatively special role within the organization, as it touches upon all national and regional divisions of Rijkswaterstaat. In contrast other large scale challenges Rijkswaterstaat faced in history, like the Room for the River-Program and the Schiphol-Amsterdam-Almere (SAA)-Program, the VenR challenge is not appointed as a formal program (as distinguished in section 2.5.1) while it simply has no tangible starting and end point. The challenge is never over, as the aging process will not stop. Therefore, the Board of Rijkswaterstaat decided to make VenR an integral aspect of the organization which has to be incorporated in the tasks all national and regional divisions. This should prevent that VenR is becoming a loose entity within the organization, like the earlier mentioned programs.

As VenR is a new and large challenge Rijkswaterstaat is facing, it logically takes time to embed in the existing organization. To support this process, it was decided to set up a VenR-team within the NOVA national division. NOVA is responsible for new developments on the intersection of content, working procedures and organization. The VenR team objectives are to monitor, advice and connect the VenR process within the related national and regional divisions. They lack controlling and guidance mandate, and operate mainly as a supportive element of the organization-wide VenR challenge. The current idea is to abrogate the VenR-team in 2023, as VenR should be naturally embedded in the organization, next to the development of greenfield projects, maintenance contracts etc.

Stakeholders

The development of the entire VenR challenge results in numerous interrelation with involved stakeholders. As discussed in the previous subsection, internally all organizational divisions are included in VenR. Outside the organization, the VenR projects touch upon the interest of other (semi) public organizations like: provinces, municipalities, water boards, network operators, rail operators and so on. From a citizen perspective, direct interest are related to the presence of local residents near the projects and the network users. Thereby, national and international enterprises are dependent on the road and water networks Rijkswaterstaat is operating. On a project level, many more (kinds of) stakeholders are involved into the VenR project. Development of VenR as a whole is therefore strongly related to these internal and external stakeholders, of which the interests all may differ. This sometimes leads to complex situations.

A.1.2 FED Process

Development of VenR is formalized in a standard procedure as shown in figure A.3. The consecutive steps all have their specific purpose and are carried out on varying organizational levels. In short, the different steps consist of the following activities:

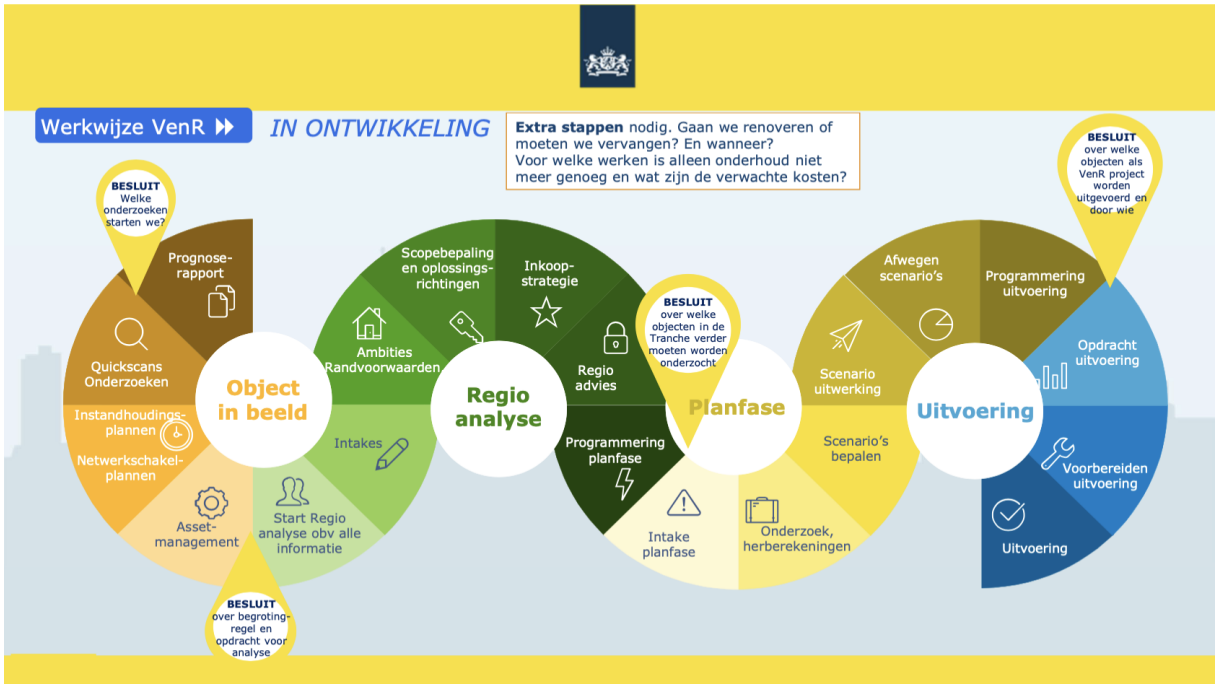

Figure A.3: Overview of the VenR process

- **Step 1 - Research program VenR and Prognosis report:**For the entire network (HWN, HVWN and HWS) of Rijkswaterstaat, a bi-annual organization-wide research program regarding the state of all assets is executed to develop a prognosis report. The research is a probabilistic forecast regarding the state of all assets, based on inspections and existing asset data. For example, the

prognosis report may state that given the knowledge on the present conditions (remaining technical life span), it is expected that a certain percentage of all steel bridges requires a MR&R intervention in the next 10 years. Based on the outcomes of the prognosis report, a necessary budget and policy is developed which will be checked by the House of Representatives. The required budget is not yet available to Rijkswaterstaat after it is checked and granted.

- **Step 2 - Regional analysis and regional advice:** With the prognosis report in mind, all Rijkswaterstaat regions are obliged to check the current state of all their assets. Based on the inspections and current data on the state of the assets, every region presents an advice regarding its own MR&R challenge. This advice consist of a list of (elements of) assets which in their opinion should be involved in the VenR scope.
- **Step 3a - Programming and update of multi-annual state budget:** On an organizational level, the regional analysis are reviewed and the cost estimations and related budget reservations are updated.
- **Step 3b - Decision moment 1:** At this point, it has to be decided whether a proposed (element of an) asset will be permanently in the VenR scope and will be added to a new Tranche. If a 1-on-1 replacement or minor adjustments to the current asset functions are expected, assets meet the requirements to get a spot in the new Tranche. However, if large adjustments to the current traffic situation or environmental demands are present a regular MIRT procedure [1] will be started. This will be outside the VenR scope, as this is mainly focused on the conservation of the current infrastructure network. Sometimes (large-scale) maintenance is sufficient, instead of renewal or replacement. If this is the case, measures are taken trough Service Level Agreements, instead of becoming part of a VenR Tranche.
- **Step 4 - Scope phase:** For all assets within the Tranche an individual intake is carried out, to determine the exact MR&R demand. Thereafter an investigation regarding the potential renewal or replacement alternatives is carried out. From these alternatives, the process diverges to one preferred alternative for the (element of the) asset.
- **Step 5 - Decision moment 2:** The preferred alternative which was proposed at the end of step 4 is to be checked by the Board. If the proposal is honored, it can pursue to the next phase.
- **Step 6 - Execution:** The process continues to the execution phase, where the design and construction will take place.

A.1.3 Occurrence of complexities

Size of VenR

Having a Tranche of 40 projects consisting of more than 130 assets in total demands a huge MR&R effort. Making decisions on the configuration of related projects is becoming more complex as all these 40 project have to be weighed against each other. Thereby, all project consist of different kind of assets, located all across the Netherlands, composed of different materials which all have a different remaining technical lifetime. Therefore not only the amount of elements but also the number of interrelations between the assets rises the complexity of decision-making.

Sequence of process steps

Project manager RI2, who was responsible for the intakes of the assets in Tranche 4, placed some question marks regarding the sequence and timing of certain process steps. After the projects were selected for Tranche 4, intakes had to take place to determine the potential MR&R interventions that have to take place. This was done by gathering facts about and around the assets, consulting inspection reports and having meetings with local asset managers, technical experts and the PPO, GPO and CIV representatives. This was done by one team which had to carry out and report all the intakes. This team was operating in an organizational overarching manner and in close contact with the regional and

1 MIRT stands for: Multi-annual Program Infrastructure, Space and Transport and consists of a procedure which is followed to realize greenfield projects in the Netherlands

local asset managers in place. Project manager RI2 mentioned that the intakes itself took six months, to gather all necessary information before continuing to the scope phase. While the assets are already checked to a certain extent during step 2, he questioned whether the intakes would not be a part of this process. By doing so, the time between decision-moment one and the actual start of the scope phase would be shortened.

Inefficient bundling of VenR activities

Another interesting aspect is related to the scope of the process and present steps. Step one starts with a global condition assessment of all assets within the organization. Thereafter, the scope changes from the entire organization towards the individual regional divisions. During step 3, the information from these regions is merged into one Tranche, which basically is a portfolio of independent assets which share a set of resources [Pellegrinelli, 1997]. Within step 4, first the intakes had to be conducted by one team which was coordinated by the organization-wide GPO department. Thereafter, the intervention alternatives are developed and tested on an individual (element of an) asset basis by the responsible regional division. Hereafter, the decision for an execution plan is determined from this same individual perspective by the region and checked by the board. From the perspective of a portfolio-focused approach, it seems that the opportunities to seek for linking opportunities between individual (elements of) assets are not actively sought. By developing a portfolio and setting up a new VenR Tranche but not using the opportunities of having a set of 40 projects with an MR&R need, the process may even gets more complicated compared to following the process on a 1-by-1 asset project-approach. For example, the intakes were organizationally-wide coordinated. After the intakes, an improved overview of the current state of all VenR assets was present, but still the projects were executed by the region itself without seeking for any clustering opportunities among all assets within the Tranche. The benefit of this time consuming intake procedure is therefore questionable.

Nevertheless, Rijkswaterstaat is currently exploring bundling opportunities for Tranche 4 and future Tranches. Various reasons caused a situation where multiple projects in Tranche 4 already started in an individual matter and with none or little interaction with other VenR projects. With the remaining projects, Rijkswaterstaat is currently exploring opportunities to bundle multiple projects. Despite a lot of projects in Tranche 4 already started and moved on to phases after the FED process, some options may still be present and could function as an example for future Tranches.
One example of bundling of VenR projects however already took place, even though this was not in line with the discussed VenR procedure. Portfolio manager RI1 made the decision to bundle 9 tunnels within the region he is responsible for in Tranche 4. This decision was made during step 2, where the region itself was responsible for the analysis. However, the initiative came from the portfolio manager himself, as he saw advantages in the bundling of 9 tunnels which all demand a renewal and alignment of their technical installations (Dutch: TTI's). *"I have 9 tunnels with more or less the same MR&R challenge within my region I am operating in. Why would I set up 9 different project teams, when one team can do the job as well. This team was even already available, as a comparable project just finished. Thereby, the Dutch market is characterized by just three or four contractors who have the correct specifications to do such specialized work like the renewal of the TTI's. This reduced the complexity of later on procurement, as only four contractors are able to do the work. As the remaining technical lifetime of the current installations is running out, I need to act quickly. Merger of the 9 tunnels into one project was therefore a no-brainer for me."* The decision to go off the beaten track by RI1 somehow raises the question whether this bundling opportunities should not be officially incorporated in the VenR process.

Resource allocation

RI3 mentioned another deficiency as for all assets after the intakes in step 4, an individual team had to be composed and related project plans have to developed. Given the amount of assets and formulated goals within the VenR, corresponding characteristics with the proposed portfolio approach seem to be present. Another reason to recommend this measure lays in the opportunity to make innovations within projects economically feasible. By having a repetitive character, investments can be spread out over a larger sum of projects. To conclude, potential compositions of these portfolio's can be determined by numerous drivers. However, consequences of a possible portfolio approach should

be investigated extensively as the VenR holds interfaces with several internal and external disciplines and actors.

Composition of project teams

An planning related issue, which was mentioned by RI1, RI2, RI3 and the forecast report of 2019 Rijkswaterstaat [2019d], was the necessary time and effort to form projects teams. Most assets need a diverse set of experts regarding technical, environmental, project management, controlling and contractual issues (the so-called Integrated Project Teams Rijkswaterstaat works with). As the amount simultaneous of VenR projects is very high and all demand several rare experts and project members in general, the scarcity of human resources leads to planning issues. This hampers the progress of VenR in its entirety. RI1 explained he had executed a tunnel project right before VenR. At the time the previous project was finished, he and the whole project team could easily shift to the VenR project. This was somehow lucky and can be seen as an exception compared to other VenR projects, which all have to form a project team from scratch. This time consuming process also influences to ability of VenR projects to get off the ground.

Coordination of execution planning

Thereby, portfolio manager RI1, who is responsible for the MR&R activities of nine tunnels in the Province of South-Holland in Tranche 4 exposed a major issue regarding the planning in VenR. As all assets are part of the road and / or water network, execution of MR&R works will influence the traffic flows within these networks. RI1: *"The VenR execution planning works on a first-come-first-serve basis, the project team which hands in the final execution plans first, can start first. This does not encounter any interrelations with other projects (outside the VenR scope), which may lead to severe congestion in the future. If I would simultaneously execute MR&R works to all tunnels within my portfolio, it would lead to severe traffic infarcts in the South-Holland region. Execution of MR&R works and related planning need nation-wide coordination, which is currently not the case."*

A.2 CASE 2 – KUNSTWERKEN AMSTERDAM–RIJNKANAAL GROOT ONDERHOUD (KARGO) – RIJKSWATERSTAAT

In this section, the KARGO program will be analyzed thoroughly in order to create insights in the decision-making process and related trade-offs to provide input for future MR&R projects or programs.

A.2.1 Program details

Purpose and program definition

For decades, the Amsterdam-Rhine Canal is an important waterway between the Amsterdam harbour and the German Ruhr district, which makes it one of the busiest channels in the world [Movares, 2015]. The channel is over-bridged by eight steel arched bridges which were constructed between 1934 and 1976. Due to deferred maintenance, a messy appearance and structural defects due to severe deterioration like corrosion and chloride impairment, all bridges demanded significant maintenance [Reusink, 2013]. Thereby, the inland shipping business was developing as well, demanding the shipping routes to be suitable in favour of container barges with four layers. Therefore, the following program objectives were stated up-front:

- Merge all bridges in one program and one contract - Given the similarities in physical characteristics and corresponding location on the Amsterdam-Rhine Canal, it was determined to combine the eight bridges in one contract.
- Comply to the existing safety norms and regulations for the coming 30 years - transition to the new Eurocode standards and guidelines to be ready for the next three decades.

- Adapt the height of the bridges to make four layer container shipping possible - Preserve the ability to cross the Amsterdam-Rhine Canal for even higher container ships to keep it an attractive route between The Netherlands and Germany.
- Minimize traffic disruptions - Make sure the MR&R works obstruct with the connected traffic routes to a minimal extent.
- Safeguard trustworthy program data - Assure that data during the program is up-to-date to coordinate the progress.
- Guarantee safety - Make sure that safety (in the broad sense) is not at risk.
- Sustainable commissioning - Take sustainability measures into account as criterion while selecting a contractor.

Meeting the above objectives will result in future proof transportation solutions for all different kind of network users. Striking aspects is that the success of the program is also partly dependent on the performance during the program (process) next to the achievement of the key outputs.

Program facts and figures

In figure A.4, the overview of the KARGO program is provided. The blue line is visualizing the Amsterdam-Rhine Canal.

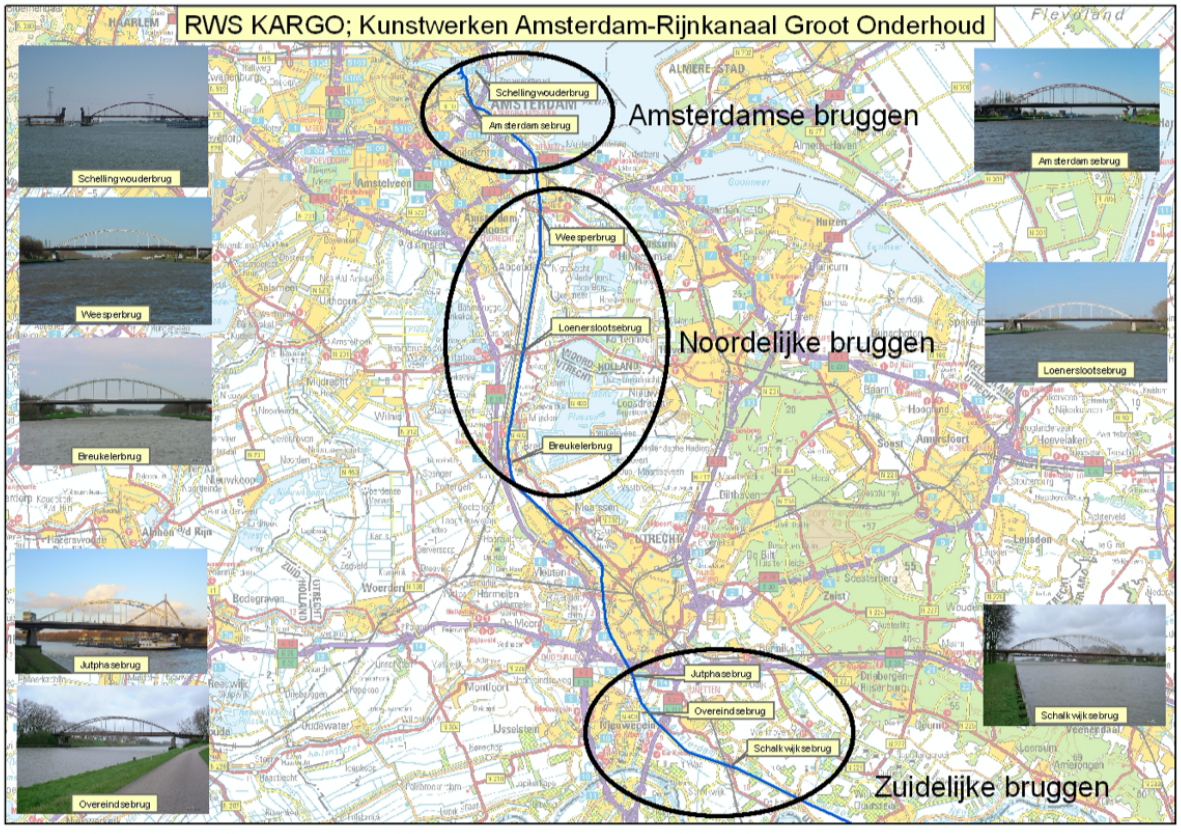

Figure A.4: KARGO program overview

From north to south, the following bridges were included in the program:

1. Schellingwouderbrug - Amsterdam (North-Holland), crossing the Buiten-IJ right after the mouth of the canal
2. Amsterdamsebrug - Amsterdam (North-Holland)
3. Weesperbrug - Weesp (North-Holland)

4. Loenerslootsebrug - Loenersloot (Utrecht)
5. Breukelerbrug - Breukelen (Utrecht)
6. Jutphasebrug - Utrecht (Utrecht)
7. Overeindsebrug - Nieuwegein (Utrecht)
8. Schalkwijksebrug - Houten (Utrecht)

MR&R elements

Interesting aspect of this program was the determination of MR&R activities. Rijkswaterstaat was in advance unaware whether some bridges had to be renewed or replaced. This was due to the earlier discussed uncertainty (in section 2.5.1) regarding the exact state of certain parts of an asset. While Rijkswaterstaat as the client could not and wanted not to determine the MR&R works of the bridges, this responsibility was left with the bidding contractors. During the tender phase, contractors willing to get the KARGO contract had to determine whether a bridge had to be renewed or replaced. The final bid of the three contractors that signed up for the contract is shown in table A.4.

Bridges	**Construction year**	**Consortium A**	**Consortium B**	**Consortium C**	**Final decision**
Schellingwouderbrug	1958	Replace	Replace	Renew	Replace
Amsterdamsebrug	1957	Renew	Renew	Renew	Renew
Weesperbrug	1937	Replace	Replace	Replace	Replace
Loenerslootsebrug	1937	Replace	Replace	Replace	Replace
Breukelerbrug	1957	Renew	Replace	Replace	Replace
Jutphasebrug	1936	Renew	Renew	Replace	Renew
Overeindsebrug	1937	Replace	Renew	Replace	Replace
Schalkwijksebrug	1971	Renew	Renew	Renew	Renew
	+				
	Ratio Renew/ Replace	4 / 4	4 / 4	3 / 5	3 / 5

Table A.4: MR&R decisions of the different consortia

Based on their individual bridge assessments, the bidding consortia offered either four or five bridges to be replaced. By replacement is meant, the replacement of the steel superstructure of the bridge. All involved parties unanimously decided that the Weesperbrug and the Loenerslootbrug had to be replaced. After the review of the tender bids, Rijkswaterstaat selected consortium A. The interviewed program manager of the KARGO program explained Rijkswaterstaat had the initial idea to only replace one and renew seven bridges. How could it be that the renew / replace ratio shifted from an initial 7/1 to a 3/5 ratio? This was mainly due to the large levels of uncertainty regarding the exact state of the bridges. As the program manager explained: *"It is extremely hard to tell what is inside a bridge before you open it up. Sometimes you think that you know what to expect, but the reality often appears to be completely different. Deterioration of certain bridge components was in some cases way worse than expected. This does not say that the maintenance inspections were carried out inappropriately. On the outside it is simply hard to tell what is on the inside.* As a consequence of the inspections of the winning contractor consortium after the program reward, it appeared that the proposed renewal / replacement plans had to be revised. This had significant effects on the program scope, planning and expenses, which will be further elaborated on the following subsections.

Finance

Based on the winning bid made by Consortium A, the initial program budget was estimated to be €87 million excluding taxes (= +/- €110 million including taxes). [2]. However, the final costs were 38% higher. An overview of the expenses is table A.5.

2 The price cap was set at €88 million by Rijkswaterstaat

Bridges	Renew / Replace	Bid (x10^6€)	Add. costs (x10^6€)	%	Main reasons
Schellingwouderbrug	Replace	20.6	6.5	32	Hidden concrete damages and new architectural rendering
Amsterdamsebrug	Renew	18.9	14.2	75	Hidden concrete damages and bad condition of bicycle bridge
Weesperbrug	Replace	11.6	0.5	4	Bad condition of abutments
Loenerslootsebrug	Replace	17.3	1.8	10	Bad condition of abutments and hidden steel damages
Breukelerbrug	Replace	12.8	11.3	89	Initial plan and bid was to renew, and strict (new) steel regulations
Jutphasebrug	Renew	9.3	7.0	75	Strict new steel regulations and hidden steel damages
Overeindsebrug	Replace	9.5	0.4	4	Additional costs for cables and pipes
Schalkwijksebrug	Renew	10.1	0.6	6	Additional costs for cables and pipes
	+				
	Sum	**110.2**	**42.3**	**38**	

Table A.5: Expenses overview of the KARGO program

Main reasons for the different between planned expenses and actual expenses were the change from renewal to replacement of the Breukelerbrug and mostly hidden steel and concrete damages in the components of the bridge.

Planning

Overview of the program delivery dates of KARGO are shown in figure A.5.
While replacement of bridges takes shorter than renewal, the final construction time of the entire KARGO program took a relatively short time. As Program manager RI2 explained, the replacement of the first two Bridges was challenging for the entire team. However, as the entire team was learning from the experiences of replacing bridges, it became more of a routine. This resulted in very limited risks and a lot of confidence for the entire team while replacing the last couple of Bridges. Learning from the previous replacement interventions was therefore mentioned as a major advantage for the progress of the execution of the KARGO program.

Contracting

For the KARGO program it was decided to bundle all KARGO bridges into one Design and Construct (D&C) contract with a duration of 6 years (2011-2016). Merger of the eight bridges in one contract should provide the contractor with the ability to benefit from the economies of scale and repetitive character of the MR&R preparation, design and execution works. The antecedent procurement phase was focused on a competitive dialogue. Contractors had a lot of freedom as the (earlier mentioned) performance requirements were formulated on a high level of abstraction. Selection of the preferred bidder was based on the so called Economically Most Advantageous Tender (Dutch: EMVI, Economisch Meest Voordelige Inschrijving). This means the selection was not primary based on a price criterion but also accounted qualitative aspects. This included objectives regarding the nuisance, program management

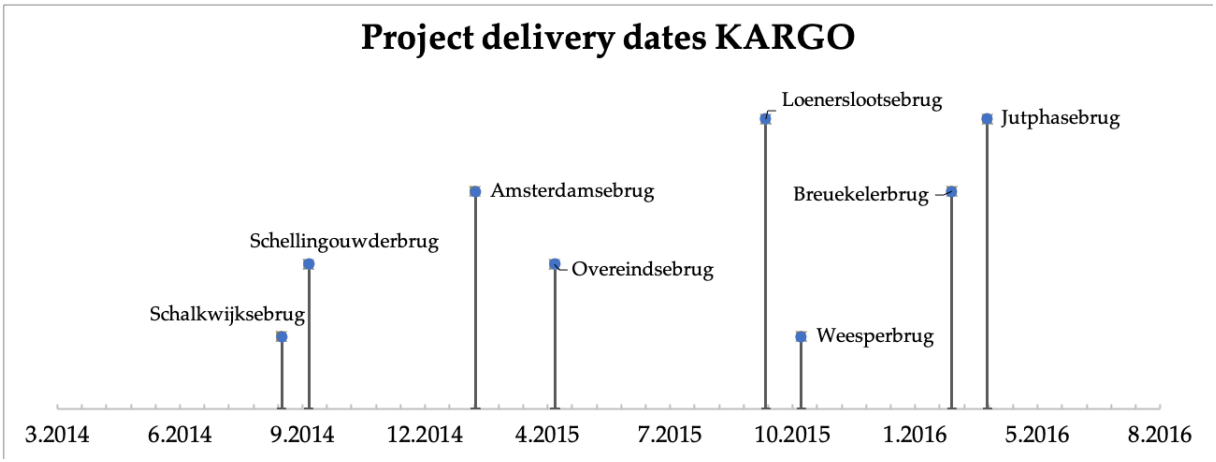

Figure A.5: Project delivery dates of the KARGO program

approaches and safety. Proposals which encountered this elements could get a fictitious bonus on the tendering bid. This decreased final bid was compared to the bids of the other contractors.

As part of the bid, all contractors had to include a detailed trade-off between renewal or replacement per bridge. The nuisance objective in the EMVI criteria included a calculation regarding the costs of obstructions during the execution of MR&R works. Next to the fictional bonus structure, there was also a non-fictional penalty imposed on not fulfilled nuisance promises during the execution. This penalty was developed to prevent speculative and unrealistic bids. Afterwards, it was questioned whether the fictional bonus of minimizing obstructions was in proportion to the effect on the final bid. Including this criterion resulted in a strong shift of renewal to replacement as some objects had relatively high obstruction costs. For future program, it was recommended to revise the impact of the obstruction criterion on the final bid as potential renewal possibilities were potentially missed in KARGO.

Organization

The organization of the KARGO program was a collaboration of the regional divisions: Central-Netherlands (MN) and West-Netherlands-North (WNN) and the national division of: Large projects and maintenance (GPO). To prevent organizational complications, it was decided to coordinate the program trough from the office of the regional division of Central-Netherlands (MN) in Utrecht. Reason for this decision were made because most bridges were located in the region of Central-Netherlands, due to the ability to have one overview of the expenses and potential losses, to have one central management and to communicate to all stakeholders in an uniform manner. The composition of the teams however consisted of all of the earlier mentioned Rijkswaterstaat divisions.

Stakeholders

Program manager RI2 mentioned that the merger of two regional divisions in one program team seemed to have significant advantages in the light of stakeholder management. While the regional divisions were in close contact with the involved stakeholders like municipalities, provinces, water boards, public transport operators and emergency services, coordination of the MR&R activities was easier due to the existing contacts with these stakeholders. Thereby, the users of the canals and bridges had to be informed regarding the obstructions and available alternative (shipping) routes. Communication of (partial) obstructions as a consequence of MR&R activities was part of a standard procedure and done by a special team responsible for communications. The attitude of the local residents towards the KARGO process was considered positive as they felt connected to this program. Replacement of the bridges was even accompanied by large crowds of local residents watching 'their' old bridge being replaced by a new version.

A.2.2 FED Process

Exact reconstruction was of the preparation of KARGO hard to develop, as it was already 12 years ago that the FED took place. Together with the program manager and the program evaluation document a compact reconstruction of the decision-making process was made:

- **Step 1 - Determination of MR&R demand of multiple bridges:** Asset managers in the responsible areas acknowledged the MR&R need of multiple bridges in their region as certain elements of the bridges were reaching the end of their technical life span.
- **Step 2 - Organizational decision to merge 8 bridges in KARGO:** Based on the observation of the asset managers and an initiative of the project team to gain efficiency benefits, the Board of Rijkswaterstaat accepted the proposal to merge 8 steel bridges in one program, called KARGO. This decision was based on a combination of circumstances caused by the need for a heightening of the bridges, which were all located across the Amsterdam-Rhine Canal and all having a steel superstructure with more or less the same length. Given the estimated costs of the program, it was decided to accommodate KARGO at the GPO division.
- **Step 3 - Objectives setting and preparation of tender procedure:** Given the size of the program, significant preparations were needed. To accommodate the tender procedure, a set of objectives was formulated which were intended to be fulfilled during the program. Setting the objectives was accompanied by developing certain agreements with important stakeholders like municipalities and waterway managers to incorporate their interests. Thereby, Rijkswaterstaat intended to provide as much information beforehand regarding the state of the assets. This was done by conducting condition descriptions of all involved bridges based on inspections, old drawings and earlier renovations. As comparison of the bids had to be done in an objective manner, Rijkswaterstaat developed certain calculation methods (like earlier discussed the obstruction calculations) which the contractors were obliged to use for their bids.
- **Step 4 - Selection of preferred contractor:** Based on the stated selection criteria, the different bids were compared and finally led to the decision to select one preferred contractor. As the contract was a Design and Construct contract, the entire designs still had to be made. Selection was primary therefore based on the proposed compliance to the EMVI criteria and offered price, instead of global execution plans.
- **Step 5 - Execution of MR&R works:** These global design and execution plans were developed as part of the contract. Execution of additional inspections and tests led to an increased insight in the actual scope of the program. Based on this information, the contractor in close collaboration with Rijkswaterstaat developed the detailed execution plans to either renew or replace the 8 bridges.

A.2.3 Occurrence of complexities

Uncertainties in the conditions

Execution of renewal interventions appeared to be more complex and expensive as it was very hard to determine the exact scope of the works beforehand. Renewal goes hand in hand with the existing complex structural dynamics of an asset. Based on visual inspections it is often hard to determine what is needed to upgrade an asset for the next coming decades. This complexity led to a situation where the actual MR&R works changes from the tender bid of the selected contractors. Program Manager RI2 therefore proposed to exclude the technical assessment of the asset in the early tender phase. This is in line with the new ideology of Rijkswaterstaat to apply a two-phased contract. During the first phase, potential contractors can submit a bid based on qualitative criteria. After this phase a preferred contractor is selected. In consultation with Rijkswaterstaat, this selected contractor works on detailed designs and develops a price of the work [Rijkswaterstaat, 2019b]. Working in this two phases manner excludes the time and effort of multiple contractors to make detailed designs and a price estimation during the tender phase, whereas only one contractor will finally get the contract. Even then - in the case of KARGO - the proposed tender plans were eventually not correct as the state of an asset seemed to be different than expected. Excluding the detailed condition assessment and program plans of the preparatory phase of the MR&R program is therefore seen as an useful improvement of the process.

Size of the program

Renewing or replacing eight bridges is always more complex than one. More effort is simply required. Interviewee RI2 mentioned that in the beginning of the program a lot of problems occurred and after the execution of two bridges, the entire contingency budget was already spent. However, as KARGO continued the advantage of repeating the same work starts and the process starts to smooth out. If KARGO would be eight separate projects with separate project teams and contractors, the total efforts would be significantly larger than compared to the executed cluster of the eight bridges. Therefore, the size of KARGO is a complexity but also an opportunity.

Working with outmoded technologies

Steel regulations change over time. Constructions which were built decades ago consist of technologies which are not used anymore. In the case of renewal, working with these old techniques resulted in difficult trade-offs between renewal or replacement. For the Breukelerbrug, the first idea was to renew the bridge. However, after some time it became clear that renewal would cost so much, it would not be economically efficient compared to replacement. Given the current techniques, it is often not possible to renew the bridge appropriately in an efficient manner.

Close collaboration of three Rijkswaterstaat divisions

Traditionally, maintenance activities are all coordinated by the regions. Asset managers work in their own domain and are used to carry out their activities with no or little collaboration with other regions. As the demographic conditions of the KARGO program covered two Rijkswaterstaat regions, collaboration was demanded. The decision to merge and coordinate all activities from one location, required new forms of collaboration. Naturally, representative of one region had there prime focus on their own area, instead of the program in general. Alignment of interest and joining forces demanded therefore a new mindset and took some time to develop. As these regions normally do not cooperate on a daily base, attention had to be paid to the set up of the team and alignment of objectives. In practice, this seemed to take more time then expected and therefore increased the complexity of the program from an organizational perspective.

Timing and content of decision-making

In order to create comparable tender bids, certain calculations and trade-offs had to be included by the participating contractors. Such calculations were related to expected obstruction duration of the planned MR&R activities and the effect of certain renewal interventions on the LCCA of an asset. The calculations should result in the trade-off of an contractor to renew or replace a bridge and associated costs. Altogether, these calculations led to a final bid which could be compared by Rijkswaterstaat. Including such calculations seemed logic from one perspective, as the bids of the different contractors had to be compared. However, one golden lesson of the ex-post evaluation of KARGO was that determination of the exact condition and the related trade-off between renewal or replacement is extremely hard to make during the FED. As the actual conditions of an asset are revealed at the moment you start 'opening up' a bridge, beforehand trade-offs are simply based on too limited information. Therefore the question arises: what is the added value of letting all contractors conduct their own (LCCA) calculations and making trade-offs on related MR&R activities, when the necessary information is simply not present? Perhaps it would be useful to select a preferred contractor on different criteria and determine the exact MR&R need and related costs in a later stage, after the contract reward. This again, is also in line with the new ideology of the earlier mentioned two phased contracts of Rijkswaterstaat.

A.3 CASE 3 – PROGRAM BRIDGES AND QUAY WALLS – MUNICIPALITY OF AMSTERDAM

This case is focused on the Programma Bruggen en Kademuren of the Municipality of Amsterdam. While having a history of deferred maintenance and a busy environment, the challenge of the Municipality is to say the least challenging.

A.3.1 Project details

Purpose and project definition

The bridges and quay walls of Amsterdam are both essential and historical connections. With a seventeenth century canal ring area inside the center of the city that is on UNESCO's World Heritage List, it underpins the duty of the Municipality to preserve the history, safety, accessibility and future-proofing of the city. Amsterdam has a long history of deferred maintenance, with little attention to the state of their bridges and quay walls. Nowadays, the effects of this negligence are becoming evident. Incidents, (partly) closures and emergency measures are the ugly reality of the current circumstances in Amsterdam. A large-scale approach is therefore more than necessary to do something about this urgent, complex and long-term challenge [Gemeente Amsterdam, 2019].

Establishment of the PBK is intended to fulfill the following objectives:

- Safeguard the safety and functionality of the bridges and quay walls
  - Reduce risks on incidents
  - Mitigate the consequences of calamities
  - Involve and prepare the direct surroundings in the process
- Take care of a functioning city during the MR&R works
  - Offer alternative travel solutions
  - Create mitigating measures regarding travel times
  - Clear information provision and communication with accessible contact opportunities
- Creating an achievable programming of the MR&R challenge
  - Reduce deferred maintenance
  - Increase the MR&R work rate
  - Incorporate the interest of nearby residents, local entrepreneurs and users in the relation to the state of an asset
  - Create an improved insight in the actual state of the assets
  - Improve the predictability of corrective maintenance
- Optimizing and innovating the processes and working procedures
  - Look beyond standard procedures
  - Create commitment among involved stakeholders
  - Create mandate for program directors for customized steering
  - Simplification, innovation and optimization of preparation and execution of works to speed up and reduce nuisance of the MR&R works
  - Incorporate other ambitions of the municipality (e.g. city logistics, car-free zones, sustainability and waste collection over water)
  - Integrate new functionalities into the bridges and quay walls (e.g. underground waste collection and charging stations for electric vehicles) inside the PBK scope

Considering these objectives of the program, the municipality of Amsterdam aims to execute the necessary MR&R works to conserve the bridges and quay walls of the city.

Project facts and figures

To get an overview of the total challenge Amsterdam is facing, figure A.6 is developed. The PBK encounters traffic bridges and quay walls that are expected to need a MR&R intervention in the (nearby) future and play an important role in the functioning of the city.
Bridges and quay walls exist in numerous shapes, sizes and materials. Quay walls are mostly brickwork covered quay walls. Bridges can be subdivided in:

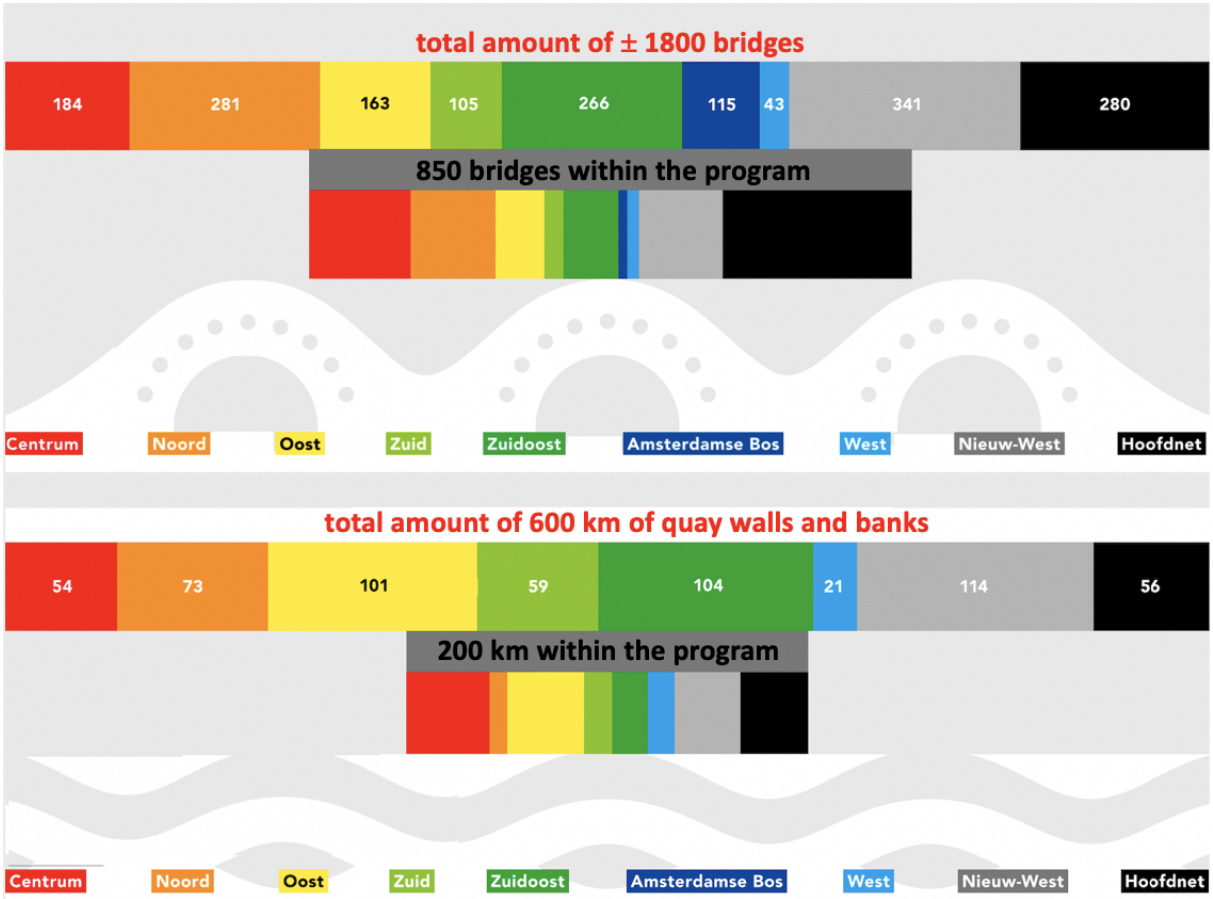

Figure A.6: Overview of the amount of bridges and quay walls within the PBK

- Movable bridges
  - 38 small-sized movable bridges
  - 42 medium-sized movable bridges
  - 16 large-sized movable bridges
- Solid bridges
  - 52 bricked welfbridges
  - 316 wooden bridges
  - 235 wooden bridges with steel beams
  - 688 small-sized concrete bridges
  - 66 large-sized concrete bridges
  - 247 small-sized combined steel and concrete combination bridges
  - 78 large-sized combined steel and concrete combination bridges

MR&R elements

While the PBK at the time of this research is still partly in the FED phase, it is not determine yet which bridges and quay walls are going to be renewed or replaced and when. The method to support the decision to either renew or replace is partly based on the safety criteria. Given the fact that 20% of the bridges is older than 100 years and 52% older than 50 years, insight in the state of the assets is critical. The PBK is working with a classification (as shown in figure A.7) of the total area based on a risk-assessment. This risk assessment is simply based on the equation: $risk = chance \times consequence$.

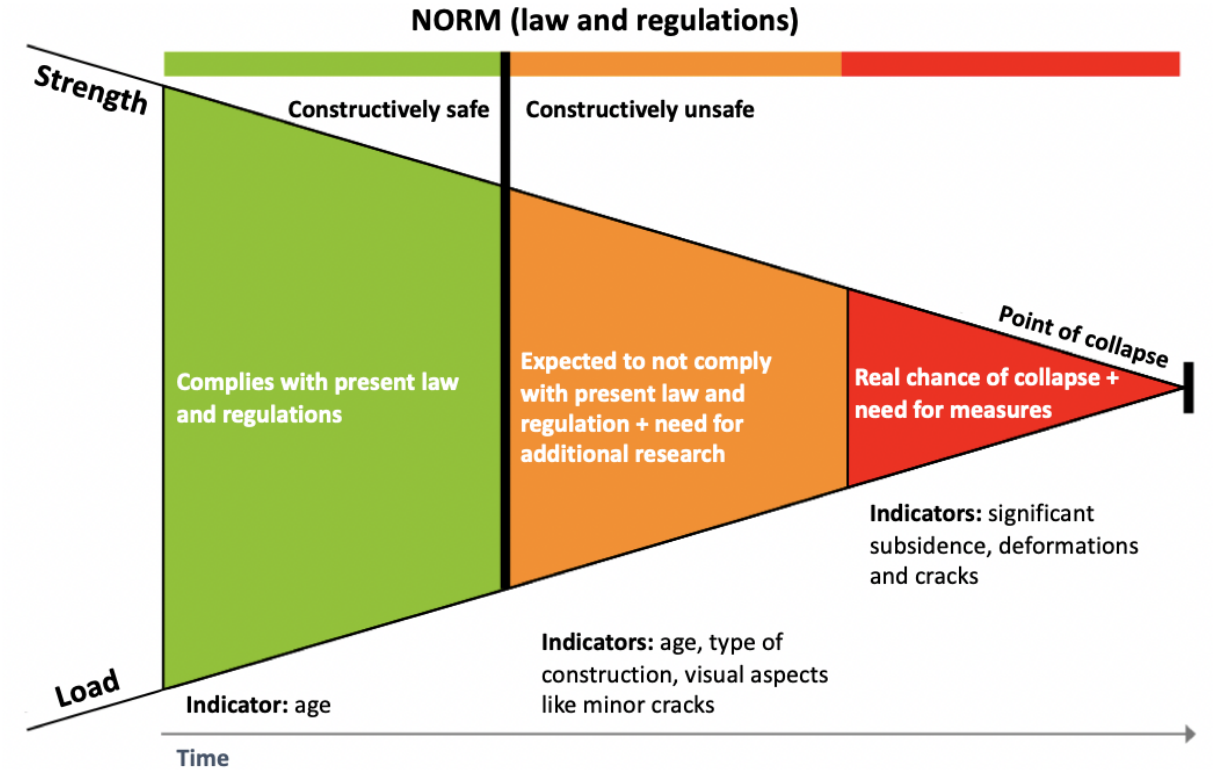

Figure A.7: Categorization of the assets within the PBK

Finance

The Municipality was facing difficulties in dealing with the flexibility demands of MR&R projects in the past. As MR&R projects are subject to high levels of uncertainty, committing appropriate budgets in early phases is difficult. The Municipality faced that the existing financial system was too rigid to perform quickly and decisive. To deal with these dynamics, the Municipality developed a new system which covers both structural budgets instead of incidental budget and has room for flexibility in time, assets and activities between the budgets. The new system exceeds coalition periods and exists of four main cornerstones:

1. **Replacements** - The available budget for the replacement projects are part of a multi-year conservation program, which are re-calibrated and indexed on a yearly base. This yearly re-calibration is done on the revised regulation-based cost calculations of the area mutations.

2. **Research, incidents, enforcement, monitoring and innovation** - To deal with the current issue of large-scale deferred maintenance, a yearly budget (from 2023) of € 15.1 million will be structurally available. This will function as a reserve to provide room for flexibility. Main aim is to stabilize the current situation of deferred maintenance and to catch up on overdue maintenance.

The first two cornerstones are specifically related to the PBK, while the next two cornerstones are part of the new financial system but are not of direct importance to the PBK

3. **Large-scale maintenance** - Structural budget with reserves to carry out large-scale maintenance

4. **Daily maintenance** - Structural budget to keep up with the daily maintenance demands

Altogether, the current estimation is that the Municipality needs € 150 million per year, given the severe backlog in asset maintenance. This is about double of the original MR&R budget of the Municipality. Since it is certain the Municipality is seriously lagging on maintenance, they lack a lot of alternatives to deal with the current situation.

Planning

With 850 bridges and 200 kilometers of quay walls within the program, realization is perceived to take at least 20 years. At the time of this research, a fixed planning for the coming decades was lacking. However, between 2019 and 2023, preparation and execution of 4.5 kilometers quay wall and 27 bridges is planned. Interviewee AI2 and AI3 admitted that this four year planning is below the necessary renewal and renovation rate. If the Municipality wants to catch up on their deferred maintenance and carry out necessary MR&R works, they have to improve their yearly MR&R rate. A detailed explanation of the proposed approach to get to this increased MR&R rate which is simultaneously in line with present requirements and resources is provided in subsection A.3.2.

Organization

To deal with the scope of this enormous challenge, the Municipality of Amsterdam decided to use a programmatic approach combined with a directly related Program Board. The decision to choose for this organization structure arose from the fact that direct control and steering opportunities are necessary to execute the PBK in a structured manner. An overview of the organizational structure is provided in figure A.8.

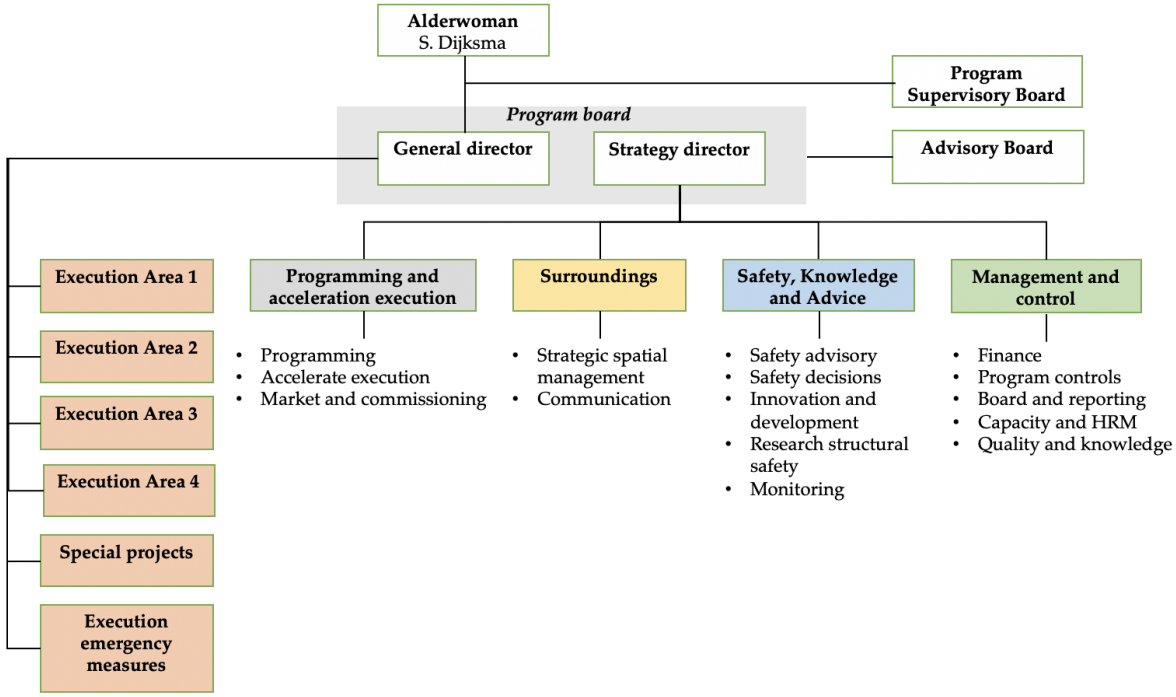

Figure A.8: Organizational structure of the PBK

The Program Board is responsible and has the decision-making authority over the entire program. They aim intergrally on safety, research, innovation, policy, environmental concerns, business operations and the programming of replacement of bridges and quay walls. The Program Board reports directly to the Alderwoman, under falls under the umbrella of the Board of Traffic and Public Space. As being part of the Board of Traffic and Public Space, connections with other organizational networks and policy goals like city mobility and asset management are made.

Stakeholders

The city of Amsterdam with its dense city center, accommodating public facilities for thousands of inhabitants, tourists and enterprises now have to find convenient ways to carry out its huge PBK. The Dutch expression of ”building on a post stamp” is part of the daily challenge within Amsterdam. Next to their duty to maintain the safety of all assets in the city, they have to cooperate with numerous different stakeholders. Nuisance of the MR&R activities of the PBK is inevitable. However, to manage all other interest in the city the program should encounter the concerns of the following stakeholders:

nearby residents, local enterprises, all sorts of road and waterway users, tourists, emergency services, network operators, public transport operators and so on.

To manage the bunch of varying interests, PBK developed a engagement plan. This plan has the aim to maintain a functioning city for all stakeholders despite the impact of the MR&R activities. The plan is actively searching for the interest of stakeholders to create sufficient mitigation measures, to involve the close surroundings at an early stage of the program, to communicate in a transparent and trustworthy way. Underlying thought of this plan is to involve and create commitment among the parties which have an interest in the PBK, by listening to their interests, informing them well and clarifying the rules and limitations of the program. A separate institution is established to take care of potential losses due to damage caused by the PBK and another team is set up to enforce the rules and policy which is mainly related to the use of heavy vehicles and trucks on unstable assets. By taking all these measures, the Municipality of Amsterdam aims to carry out the PBK in an expedient and convenient manner for all involved stakeholders.

A.3.2 FED Process

The process which shapes the progress of the PBK is formalized in a standard procedure, as shown in figure A.9. All steps of the process have a defined purpose and are carried out by several organizational units. The content of the process is as follows:

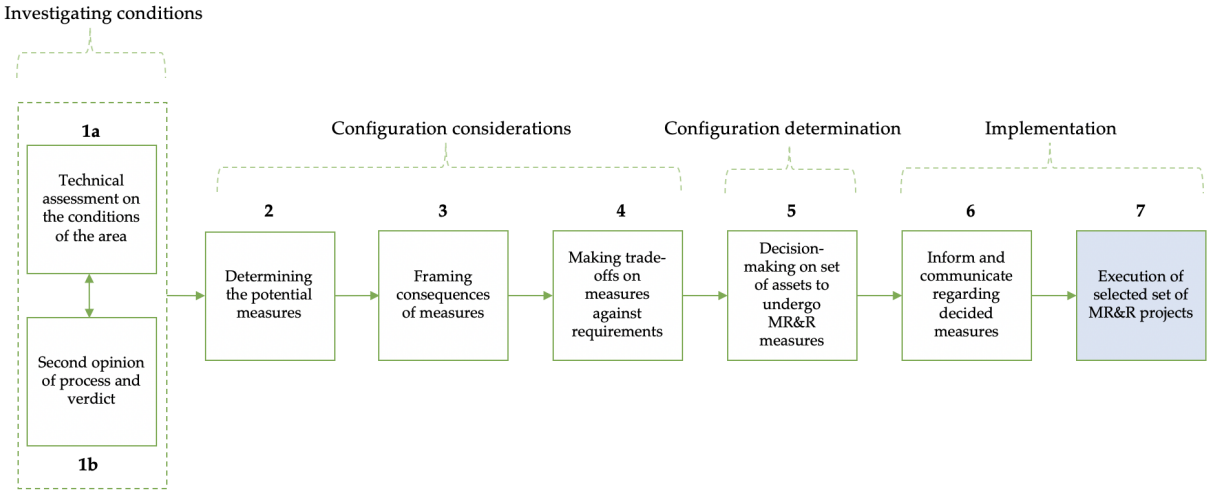

Figure A.9: Overview of the PBK process [Gemeente Amsterdam, 2019])

- **Step 1a - Technical assessment of asset conditions:** The technical state of the entire bridges and quay wall ordnance of Amsterdam is assessed based on objective criteria. After the assessment took place, assets get categorized according to the their risk profile as shown in A.7. This categorization should provide a global, city wide overview of the state of the assets Amsterdam in management. After the entire categorization took place, the presumption regarding the extent of deferred maintenance was confirmed.
- **Step 1b - Second opinion on process and verdict:** Parallel to the condition assessment, internal and external experts conduct second opinions on the assessment process and the technical assessment itself. This process takes place on an iterative basis, which results in revision and tightening of the categorization and the technical risk assessment.
- **Step 2 - Determining the potential measures:** Taken from the requirement of 'safety first', the potential measures can be divided into: guarding the asset, reduce the load on the asset, enforce the asset or perform additional research regarding the state. For assets in the most vulnerable and critical category, the situation is investigated in more detail. Scenario's will be developed with a mixed risk profile, proportionality of the measures and the consequences. This is process

is carried out with a high level of detail, which results in a proposed measure or set of multiple measures per asset. At the same time, the Municipality develops more generic solutions regarding the remaining assets which have a lower risk profile. This are measures which reduce safety risks and extend remaining technical life spans. Examples of such measures are limiting the accessibility of heavy vehicles on and around vulnerable assets.

- **Step 3 - Framing consequences of measures:** As the city of Amsterdam is characterized by high traffic rates, close proximity to other assets and limited space for construction sites, MR&R works will have significant impact. It is therefore key to frame the consequences of certain measures, as they will have severe impact on other requirements.

- **Step 4 - Trade-offs on measures against requirements:** Trade-offs among the considered measures are necessary is a process full of dilemmas. As interviewee AI1 mentioned, Amsterdam currently faces a situation where a significant amount of assets does not comply to the existing laws and regulations regarding safety. However, the immediate closure of these assets is not possible according to the Municipality. Together with important stakeholders, several points of attention are developed which are incorporated in the trade-off framework. As some requirements are simply critical, their are weighted more important then others. The necessity for emergency services to reach all parts of the city, citizens to enter their houses and be able to get rid of their garbage are some requirements which simply can not be harmed. Searching for alternative solutions and mitigating measures is therefore an important process related to these trade-offs.

- **Step 5 - Decision-making on set of assets to undergo MR&R measures:** Based on the trade-offs of the previous step, a decision is made together with a package of measures. This decision is checked and approved by the Program Board.

- **Step 6 - Inform and communicate regarding decided measures:** After the decision is made, extensive communication and explanations are provided to the stakeholders.

- **Step 7 - Execution of selected set of MR&R projects:** If physical measures are part of the decision, these are executed by the emergency execution organization. This organization is divided in one team for incidents and two for interventions for bridges and quay walls separately. These intervention teams collaborate with one or multiple contractors. By having this collaboration, preventive measures can be implemented quickly which is often necessary given the state of an asset.

1. The determined urgency of action according to the (poor) state of the asset leads to a first categorization of assets, in addition to the condition rating. This is often done as the main priority of public authorities is to maintain the safety of the infrastructure.

2. An identification of measures is added to the process, which could be taken to deal with the aging assets. In this context, measures are considered as alternative project configuration options to deal with the aging assets. To find a suitable configuration for the future MR&R projects, it could be relevant to know what opportunities are available to compose a project. Thereby, the categorization of assets is added to the condition rating phase.

3. The final decision regarding a configuration of projects to undergo a certain measure is both dependent on the criteria as on the potential measure and its consequences.

A.3.3 Occurrence of complexities

Size of the MR&R challenge

Amsterdam is large city with lots of infrastructure. All this infrastructure has to be safe, which results in a significant conservation challenge. The size of the MR&R challenge in Amsterdam with 850 bridges and 200 km of quay walls only within the PBK is an immense challenge. For all of these assets, a certain MR&R intervention has to be decided upon. These quantities, significantly increase the complexity of the decision-making regarding the configuration within the PBK.

Interrelatedness of assets

Besides the size of the city, Amsterdam and particularly the city center is a extremely dense area with numerous soon-to-be outdated bridges and quay walls in close proximity to each other. Closing of one bridge, may have significant impact on the traffic flows through the city. Together with the mentioned size of the PBK, the amount of physical interrelations between the assets complexity of the decision-making gets even bigger. Smart solutions regarding the execution of MR&R activities has therefore be sought.

Amount of involved stakeholders and related requirements

Directly and indirectly a lot of stakeholders are involved in the PBK. Besides, the interest of these stakeholders may clash in various ways. Involvement of these interest in the configuration of the MR&R projects therefore complicates the decision-making to a large extent. Local citizens logically should still be able to enter their houses and park their cars, but what if the safety of the asset is really at question? From an organizational perspective, the interest of the asset managers may be different than the divisions which are responsible for the mobility of the city. Decision-making and the use of criteria weighting is therefore considered as an important tool to come up with MR&R configurations in this jungle of interests.

Continuity of the process

Unlike projects, which have a fixed start and end date, the PBK of the city of Amsterdam is continuously going on. Simultaneously, asset inspections, execution of MR&R works, short and long-term plans for future configurations and multiple tenders are going on. While the city has a history of deferred maintenance, is the elimination of this together with 'planned' MR&R activities. For example, if numerous bridges along one channel are already known for their bad condition and planned to undergo MR&R interventions in the nearby future. The fact that the nearby bridges will reach the end of their technical life span in the (nearby) future rises the question to include these bridges also in the already planned MR&R activities. Given the intermingle of related ongoing activities, the decision-making gets more complicated.

A.4 CASE 4 – PROVINCIAL MULTI-ANNUAL MAINTENANCE PROGRAM – PROVINCE NORTH-HOLLAND

This case is about the Provinciaal Meerjarenprogramma Onderhoud of the Province of North-Holland, which is focused on low-complexity MR&R activities which are outsourced in a demographic matter.

A.4.1 Project details

Purpose and project definition

The Province is responsible for a diversity of assets, consisting of roads, waterways, civil structures, public transfer lanes and bicycle roads. Given the role of the Province, they are legally obliged to take care of the maintenance of the assets. By carrying out maintenance and replacement when needed, it is intended to keep the infrastructure up and running. In one sentence, the maintenance of the infrastructure is focused on reaching optimal performance in relation to traffic flows, livability and traffic safety in a sustainable matter [Noord-Holland, 2019].

To achieve the stated maintenance performance, the Province developed the Provinciaal Meerjarenprogramma Onderhoud (read: PMO, freely translated: Provincial Multi-Annual Maintenance Program). This program provides insight in the maintenance demand of the entire region including the required financing. Within the program, the quality is constantly assured and action is taken in the case of deviations. Leading principle in the PMO is a transparent trade-off between performance, risks and costs, which is in line wiht the ISO 55000 standard. The performance of the PMO is related to the stated objectives:

- Program performance
  - 95 % of all assets comply to the stated quality levels which are developed by the Provincial Council.
  - Minimizing delays during PMO activities
  - Operating safe
  - Reducing operational costs
  - Improving information provision
- Internal and external collaboration
  - Improving co-operation with local stakeholders
  - Linking PMO works with other internal projects
  - Improving co-operation with serving Provincial Councils
  - Improving co-operation with private parties
  - Aligning organizational structure with present challenge
- Sustainability and innovations
  - Developing and implementing innovations
  - Reducing GHG pollution
  - Reuse of building materials
  - Improving biodiversity
  - Reducing nuisance during PMO activities
  - Realizing a sustainable living environment

As can be seen from the above enumeration, the PMO objectives go beyond the performance of the program and its related assets. Incorporation of collaboration, sustainability and innovation objectives increase the scope of the program from merely technical challenges to a broader playing field of interacting elements.

Achievement of the stated objectives was decided to be most likely by splitting up the province in several regions, which all have a individual geographically bounded maintenance and management (Dutch: beheer en onderhoud) contract. By division of the Province in seven regions, the management and maintenance of the Province as a whole is determined to create improved results while improving the ability to provide both tailored solutions for every region. More details on the content of the "Gebiedscontracten" (read: GBC, freely translated: regional maintenance contracts) will be explained in the "contracting" paragraph.

Project facts and figures

An have an overview of the variety and quantity of assets the Province North Holland is responsible for is shown in table A.6:

Based on the 'Nota Infrastructurele Kapitaalgoederen 2016-2019' (freely translated: Memorandum on Infrastructure Capital Goods 2016-2019), guidelines for the required state of the assets are developed, together with a financing plan for the coming years. All assets within the region have to comply to these guidelines, which reflected in the earlier mentioned objective of: '95 % of all assets comply to the stated quality levels which are developed by the Provincial Council.' To reach this objective, the Province has chosen to separate the Province in seven individual maintenance regions with all an individual GBC. The division of the Province in seven GBC is shown in figure A.10.

The seven region have the following names:

1. Kop van Noord-Holland (Since 2015 by contractors combination: WaakSaam - Dura Vermeer, Ploegam and Van den Biggelaar)
2. Alkmaar and surroundings (Since 2017 by contractors combination: Gebiedscontract Midden Noord - BAM, Engie and Krinkels)

Type of asset	Quantity	Unit
Roads	614	km
Waterways	246	km
Bicycle roads	384	km
Buslanes	49	km
Public lighting	11.370	pc
Traffic control installations	268	pc
Dynamic Traveler Information Panel	25	pc
Fauna passages	77	pc
Stops / Stations	204	pc
Fixed structures	489	pc
Movable structures	65	pc
Bridge control center	1	pc
Traffic control center	1	pc
Tunnel control center	1	pc

Table A.6: Overview of the assets the Province North-Holland is responsible for

3. Westfriesland (Since 2017 by contractors combination: Gebiedscontract Midden Noord - BAM, Engie and Krinkels)
4. Zuid-Kennemerland / IJmond (Since 2018 by contractors combination : BAM, Engie and Krinkels)
5. Zaanstreek - Waterland (Since 2016 by contractor: Volker Infra)
6. Noord-Holland South (Since 2018 by contractors combination: Common Hearts - Van Gelder, Mobilis and De Jong Zuurmond)
7. Gooi and Vecht region (Since 2017 by contractors: Volker Infra)

Interesting aspect is the merger of regions 2 and 3. Program Manager NHI1 explained that due to the overlap of multiple main roads, it was decided that the two regions could better be merged into one contract during the procurement phase. The same combination of contractors also won the contract for region four. However, this region has its individual budget and planning.

MR&R elements

The GBC of the Province mainly exist of services, preventive maintenance and corrective maintenance. Activities differ from de-icing and ecological roadside management to replacements of road surfaces. Renovation and replacements of small sized bridges, quay walls are also part of the GBC. However, the fixed reimbursement of the GBC only consists of the services, preventive maintenance and corrective maintenance. Renewal and replacement activities and investments are not included in the budget of the GBC and are paid to the contractors on a cost reimbursement basis. Both program managers NHI1 and NHI2 mentioned that the larger MR&R activities which exceed a budget of €5 million, are not part of the GBC anymore and are procured as an individual project. The reason for this is related to the difference in complexity between the work inside the GBC and the larger MR&R investments. The contractors which are responsible for the GBC execute activities which are in essence significantly different than MR&R of complex and large structures. Therefore, these are not part of the GBC. MR&R of smaller assets which do not exceed the budgetary limit of € 5 million are considered to be doable for the contractors in charge, due to their lower level of complexity.

Finance

All GBC are based on a fixed periodical payment for the earlier mentioned services, preventive maintenance and corrective maintenance. Besides, regional MR&R expenses consist of area expansions (greenfield project), variable heavy maintenance (which exceeds the scope of the GBC) and replacement investments. These investments which are not part of the regular reimbursement of the GBC, are seen as individual investments in the overall MR&R budget of the Province North-Holland. Reservations and actualisation of the overall maintenance budget of the Province are made on a yearly base, which estimate the MR&R expenses of the coming 8 years. While the other MR&R activities, in contrast

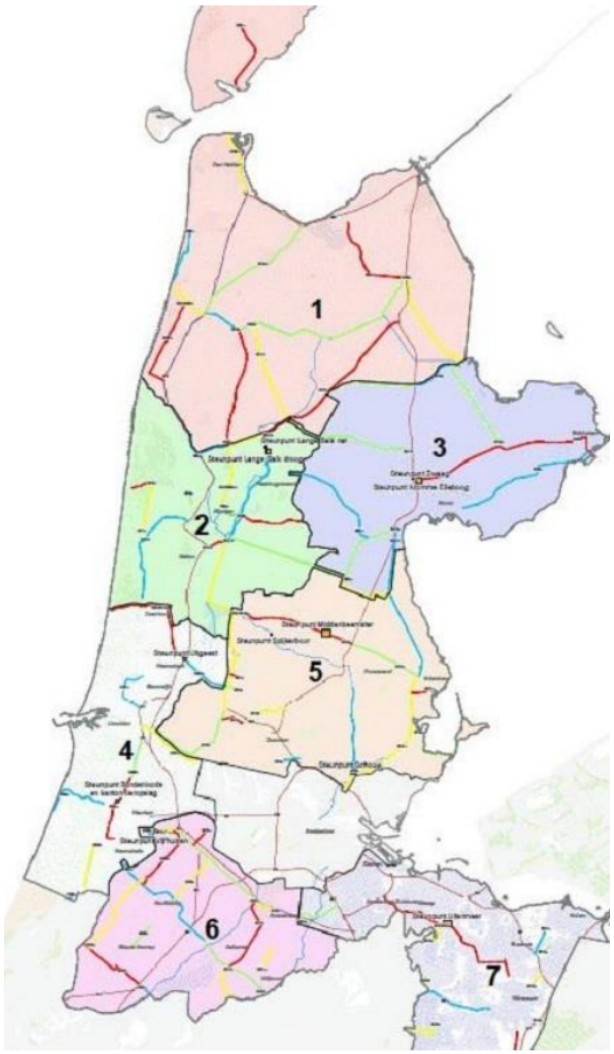

Figure A.10: Overview of the seven GBC of the Province Noord-Holland

to the GBC activities, show larger variations is yearly budget demands, these reservations are necessary to cover the expenses. After a MR&R intervention took place, the actual expenses of the intervention are withdrawn from the reservation. Interviewee NHI2 explained that this provides the necessary freedom to spend the amount which is necessary for the activities. If the budget would be limited to a fixed amount in advance, it could be that this would be insufficient for the necessary MR&R works to upgrade the state of an asset. Yearly actualisation of the reservations in the overall budget, assures there is also a budget available for all projects.

Planning

The first GBC began in 2015 and from then on the subsequent GBC started in a phased manner. In the fall of 2018, the last GBC North-Holland South was awarded and has a duration of 10 years. All GBC will take 10 years and during this period the contractor (combination) is the only player in charge of all of the before mentioned MR&R activities.

Contracting

Traditionally, the Province was in charge of all maintenance activities and used to commission every project individually. Given organizational changes and difficulties in managing the entire Province, a shift in the way of working was decided. Instead of carrying out all the coordination and commissioning by the asset managers of the Province, the idea was to shift the responsibilities to the party who is also executing the MR&R activities. By splitting the region up in seven manageable areas, the

Province was relieved of its management duties and the contractor had the freedom to plan the execution of MR&R activities when it suits him best. Program Manager NHI2 explained that creation of this freedom for the contractors should lead to lower costs of all activities within the GBC, as contractors could carry out this activities in off-peak moments as long all stated requirements of the contract are complied to.

Program manager NHI1 explained that the phased release of the contracts was a deliberate decision, as lessons learned of the previous GBC could function as input for the new contracts. *"As this was the first time the Province was working with GBC, we accepted that it would not work perfect from the beginning. Therefore, we applied a learning-by-doing approach. After the first GBC was awarded and going on for some time, we found out we forgot to mention some relevant aspects in the tender phase before awarding the contract. These adjustments were included in the the following GBC, so the same issues would not exist in other GBC. Making adjustments to a contract while it is already running is always harder and often more expensive. However, thinking that you can prepare for everything and making a perfect contract is a fairy tail. You will always face certain 'grey-areas', but learning from the past makes you more reluctant to these unwanted and uncertain aspects."* Thereby, a certain balance has to be found between the freedom of the contractor and formulation of the objectives of the Province. By reviewing the contract bids of the contractors on the earlier mentioned EMVI criteria, this was intended to also encounter qualitative aspects, instead of merely the lowers price offer.

At the time of this research, the Province had not decided yet what will be done after the termination of the GBC. Given the current positive experiences, Program manager NHI2 told that is was likely that the use of GBC will be continued in the future. Contractors now have the full responsibility to detect the MR&R needs of the area they are operating in, carry out all MR&R activities and plan the preferred execution schedule of all activities. Program manager NHI1 explained that in this way of outsourcing most responsibilities also some risks are involved. The GBC covers a time-span of 10 years and within this ten years it develops and optimizes a preferred way of working. After those 10 years, all knowledge and data is with the contractors in charge of the GBC instead of with the Province. If it is decided to not pursue the GBC, this will probably lead to significant efforts for the Province to develop a new way of executing the MR&R activities. Transfer of this GBC related knowledge the contractor possesses, is therefore an aspect the Province has to encounter when deciding upon a MR&R strategy for the future.

Organization

Both Program managers NHI1 and NHI2 stated that he experiences of responsible contractors with the structure of the GBC are very positive. For the Province itself it is however a little more complicated. Employees like asset managers which were traditionally responsible for the coordination of MR&R activities in the Province have to get used to their new role. Instead of coordinating, their current role is more of a supervising and controlling nature. Planning mandate of MR&R activities is still with the Province, which gives the contractors not the full freedom to execute the MR&R activities whenever they want. Thereby, quality assurance is also checked by the Province by conducting spot checks and reviewing quality reports. In this way, the Province is still involved and carries responsibility to a certain extent.

Stakeholders

Within the GBC regions, the responsible contractors have to align their planning with the other stakeholders. Conflicts may arise with other projects of the Province, Rijkswaterstaat, public transport operators, water boards and municipalities. Thereby, the interest of commercial and private users of the roads, bus lanes, bicycle roads and waterways should be included in the coordination of MR&R activities. This obligation to include the interest of all stakeholders was also part included in the tender requirements, by demanding stakeholder engagement plans in the bid of the contractors. To make sure, the selected contractor sticks to it promises and carries out the stakeholder management in an appropriate manner, the Province has the final mandate to grant permission for the MR&R activities.

A.4.2 Process

- **Step 1 - Urgency was raised from the Provincial Council regarding the state of the assets in the Province:** The Provincial council developed a Memorandum and a coalition agreement which stated the urgency to assure the quality of the infrastructure network of the Province North-Holland. Two programs were started, the discussed PMO (Dutch: Provinciaal Meerjaren-programma Onderhoud) and the PMI (Provinciaal Meerjarenprogramma Infrastructuur), which respectively have a focus on brownfield and greenfield projects.
- **Step 2 - Decision to outsource certain MR&R activities in a demographic manner:** Within the PMO, the Province made a distinction between several methods to assure the conservation of the infrastructure network of the Province. One of these methods was the use of geographically bounded contracts, to execute the less complex and repetitive MR&R activities by one (consortium of) contractor(s) for the next 10 years. Background of this decision was the intended efficiency of outsourcing all MR&R in one region. Instead of commissioning all of the related MR&R activities per asset individually, the whole region is covered by one contract. By having a contract time of ten years, contractors were challenged to come up with smart and innovative ideas to carry out the MR&R activities in a way that still would be profitable. Therefore, the GBC was seen as a win-win situation.
- **Step 3 - Preparation of GBC:** Together with all involved asset managers in the Province, the necessary information was gathered to secure the right conditions and related activities were included the contract. A balance was intended to be found between clear specification of the requirements and sufficient room for manoeuvre of the contractor to execute the activities in a fit-for-purpose manner.
- **Step 4 - Selection of the appropriate contractor for the GBC:** The tender bids were compared on the stated EMVI criteria. While the province was divided in seven regions and six GBC, multiple contractor combinations applied for multiple GBC.
- **Step 5 - Execution of GBC:** Once the contract had been awarded the responsibility of the MR&R activities in the region shifted from the Province towards the combination of contractors for the coming ten years.

From step 5 there is a iterative loop back to step 3, as the experiences of ongoing GBC functioned as input for the contracts which still had to be awarded.

A.4.3 Occurrence of complexities

Size of the area

With 4.092 square kilometers, the Province North Holland covers a large area which all need to be maintained. Coordination of MR&R activities for the entire region was considered to be too complex as it was simply too large. By cutting the area in seven pieces, the Province tried to divide the amount of assets in relatively equal parts, which made the content of all GBC also comparable. Program managers NHI1 and NHI2 stated that the benefits of carrying out MR&R activities on a smaller scale would be little. Regular activities like de-icing and ecological roadside management require specific tools. For example. if the region would be split up into 20 GBC, 20 de-icing trucks had to be acquired instead of the seven that are necessary in the current situation. Vice versa the same applies, as two de-icing trucks would be too few to cover the entire Province. Therefore, dividing the Province in seven regions was decided to be sufficient to cover the GBC activities in the entire area.

Diversity of assets

Considering the broad diversity of assets, as can be seen in table A.6 the variety of the MR&R activities is large. Instead of commissioning every kind of asset to a specialized contractor, the entire set of assets in one region is attributed to a contractor combination. As the complexity of the activities which are part of the GBC is relatively low, the Province decided that it is possible for on contractor combination to be responsible for all related activities. As the budget and related complexity is increasing of

an upcoming MR&R activity, a separate contract will be drawn up to assure involvement of capable contractors to execute the task. However, by separating the assets in the province on a complexity level into commodities and merging these in one contract, a lot of effort and time regarding the commissioning of these activities is safe. As the risk of defects is lower with these relatively easy MR&R activities, the Province decided to value efficiency over having complete influence on the maintenance of the Province.

New role of the Province

Instead of having full responsibility of the conservation of the infrastructure in the Province, the use of GBC shifted a lot of these responsibilities to private contractors. Asset managers which traditionally had to assure the quality of their responsible area, now only have to supervise the whole procedure. Program manager NHI1 explained that this resulted in some indistinctness regarding the division of tasks between the contractor and the Province in the beginning. As most GBC are already running for a couple of years, the way of working becomes the new standard and leads less and less to unclarities. Interviewee NHI2" "In this way, usage of GBC is more like ordering a service like companies have to clean their offices. It is a matter of trust and setting the right requirements in the contract. If these two factors are present, it works perfectly."

Short-term versus long-term benefits

While determining the application and related duration of GBC in the Province, a clear trade-off between short-term and long-term benefits was made. On the short-term (0-10) years, the Province would be unburdened with the relatively easy MR&R activities. The contractor has a significant time-span to optimize its working procedures and make improvements as it has a fixed source of income for the next ten years. However, is this decision really a decision which only covers the next ten years? As discussed with both Program managers, currently no decision has been made about the follow-up of the current GBC after the first GBC terminate in 2025. Continuing the use of GBC seems logically, but is it really the most economically efficient way to carry out the maintenance and are the service level agreements really met? Ongoing evaluations should shed further light on this. If after the GBC, the Province wants to take responsibilities back and become responsible for the MR&R itself, would they be really capable? All (tacit) knowledge is with the contractor, so is returning to the traditional way of working really an option? Program manager NHI1 mentioned the Province is currently still relatively closely related with the GBC and the contractors in place. However, financial details about the GBC are not shared which leaves some room for uncertainty regarding the economic efficiency of the GBC way of working.

B INTERVIEWS

B.1 INTERVIEW PROTOCOL

In order to gain empirical insights in the complexities which occur during the FED of MR&R challenges, it was chosen to hold exploratory interviews with the people involved in the investigated cases. In this section, the interview protocol will be explained. By discussing the purpose, intended outcomes, methodology, the interview questions and the interviewees, an overview of the protocol is developed. This protocol functions as the basis of the interviews, which are used to support the case analysis and the related development of the decision-making framework.

B.1.1 Purpose of the interviews

Given the problem statement and the related research questions in chapter 1, the purpose of the interviews is to gain empirical insights in the aspects which complicate the FED process of the cases. MR&R challenges are often accompanied by a wide variety of assets and requirements, which complicate the step from identification of MR&R needs to configuration of to-be executed MR&R projects or programs. In addition to the available case related documentation, involved persons will be interviewed to gain improved insights in the dynamics which occur during the preparatory phases of such MR&R challenges. Based on these insights, an overview of the potential challenges which occur during the FED of MR&R projects is to be created. The challenges will be sought from the viewpoint of the created theoretical background (in 2). Gathering these insights are done in relation to the developed sub-question:

- ***Sub-question 2*** *- "What are the main challenges related to the decision-making regarding configuration of MR&R projects in practice?"*

After the identification of the challenges which occurred in the cases, these insights will function as input for the development of the decision-making framework. This framework is created to show public organizations which face a MR&R challenge in what way they could potentially set up their FED. Based on the identified complexities which influence the decision-making process during the FED, key aspects (formulated as dilemmas) are formulated which are the basis of the decision-making framework. Creation of this framework is related to the following sub-question:

- ***Sub-question 3*** *- "How could a decision-making framework be designed to deal with MR&R projects in a fit-for-purpose manner during the FED?"*

Insights in the complexities and ways to deal with them, are therefore to be extracted from the interviews. Answers on these sub-questions potentially create empirical insights for public organizations on how to deal with their MR&R challenges.

B.1.2 Methodology

To properly execute the interviews and gather the empirical insights, an interview protocol (as presented in figure B.1) is followed.
The protocol consist of the following steps:

1. Draw up interview questions, based on the developed research questions
2. Determine which (potential) interviewees are to be interviewed

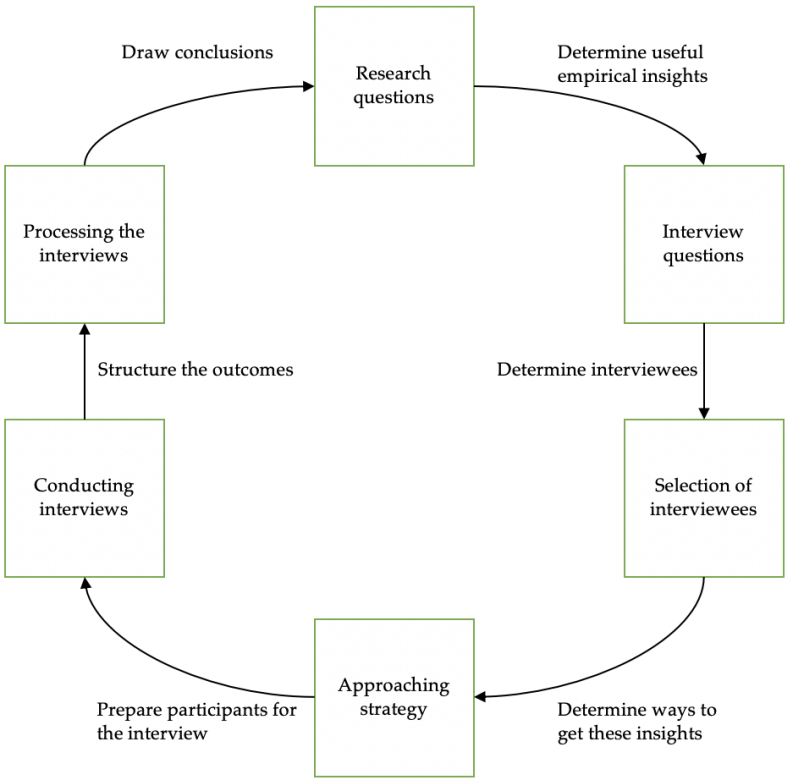

Figure B.1: Overview of the interview protocol

3. Determine a strategy to approach the (potential) interviewees
4. Conduct the interviews
5. Process the conducted interviews
6. Write down the findings to provide answers on the developed research questions

Further explanation about the related steps of the interview procedure are provided in the following subsections.

B.1.3 Interview questions

Based on the developed theoretical background, the interviews are intended to provide empirical insights on the identified complexities. The complexities, as discussed in section 2.5, are divided in both content-related complexities (asset conditions, present requirements, availability of resources, design alternatives and potential configurations) and process-related complexities (composition, sequence and scope of the FED process). To get a comprehensive overview of the way these complexities occur during the FED of MR&R challenges, interviewees should be asked to shed light on the identified complexities in the case(s) they are involved with.

Next to the identification of the complexities and the ways their influence the FED of the observed MR&R cases, the second part of the interviews is attributed to the potential ways to deal with these complexities. Interviewees will be asked about the made decisions and challenged to think about potential other opportunities to deal with the identified complexities. These insights are intended to create a basis for the to-be developed decision-making framework, which should help public organizations in structuring their FED process according to their current situation.

To turn these demands into results, the interviews will consist of the following components:

1. The context of the MR&R challenge

Since MR&R challenges may differ for every public organization, first an identification of the context is created. Questions related to the kind of assets, necessary interventions, organizational and financing structures and availability of (human) resources create an overview of the setting of a challenge.

2. Present requirements related to the MR&R challenge

To get an overview of the present requirements that play a role, interviewees are asked about the presence of various requirements in a MR&R challenge. While public organizations are obliged to safeguard a variety of public values in cooperation with private contractors and also have their own organizational objectives, this interplay of requirements is intended to be discovered. Thereby, the way organizations deal with the presence of diverse requirements is intended to be discovered, as this may provide input for the decision-making framework.

3. The outlines of the FED procedure

As observed in section 2.4.3, design of the FED may consist in numerous ways. Dependent on the purpose of the MR&R challenge, a public organization may decide to design its FED accordingly. Identification of the composition, scope and sequence of the FED will there function as a starting point for the questions. By observing four cases and asking involved persons about the chosen FED process design, the design opportunities and related trade-offs are to be identified.

4. Considered configuration options

Yet, the outcome of the FED phase is a structured set of configured projects or programs given the present MR&R challenge. Identification of the potential configuration options and the rationale behind these decisions are therefore an important part of the interviews. Identification of decision-making patterns should create an overview of the intermingle of content and process related complexities throughout the process. Which complexities are related and in what way? Thereby, the consequences of the configurations are discussed, to create an overview of the potential outcomes of made decisions in relation to the FED phase.

5. Potential consequences of decided configuration options

Next to the consequences of the decided configurations, the interviews also aim to focus on the consequences of the FED procedure itself. What potential threats and opportunities are related to the made decisions and the execution of the FED procedure. By gathering an overview of the potential threats and opportunities of decisions related to the FED design, the trade-offs which shape the FED framework is intended to be found.

Altogether, this led to a set of interview questions which form the basis of the to be executed interviews. Since the interviews are held in Dutch, the interview questions were formulated in Dutch as well. The interview questions are as follows:

De opgave

1. Hoeveel en welke assets komen in aanmerking voor vervanging en renovatie?
2. Wat voor soort werkzaamheden moeten er uitgevoerd worden?
3. Welke uitdagingen vanuit technisch oogpunt vertragen de voorbereiding van een project?
4. Kunnen werkzaamheden gecategoriseerd worden als “commodities” (= bulk / reguliere werkzaamheden) en welke “specialties (=maatwerk met lastig te bepalen scope en samenkomst van verschillende disciplines) ?
5. Welke uitdagingen vanuit organisatorisch oogpunt vertragen de voorbereiding van een project?
6. Hoe is de financiering geregeld?

Doelen

1. Welke doelen voor het project/programma waren vooraf gesteld?
2. Waarom wordt er voor deze doelen gekozen?
3. Hoe wordt het nastreven van deze doelen intern gecommuniceerd & opgenomen in de werkprocessen?

Proces

1. Uit welke stappen bestaat de voorbereiding van een project?
2. Welke beslissingen worden er genomen in elke stap?
3. Welke expertises intern en extern betrokken bij de voorbereiding?
4. Wie neemt uiteindelijk de beslissingen? Wie heeft het mandaat?

Alternatieven voor project configuratie

1. Welke project configuratie mogelijkheden zijn overwogen?
2. Waarom is er uiteindelijk voor deze configuratie gekozen?
3. Wat zijn de resultaten (tot zover) van deze keuze?
4. Zou het de volgende keer weer zo gedaan worden?

Factoren die invloed hebben op het succes van een configuratie

1. Wat zijn de aanwezige bedreigingen voor het project?
2. Waardoor ontstaat deze bedreigingen? / Hoe kan deze bedreiging werkelijkheid worden?
3. Waarom vormt dit een bedreiging voor het project?
4. Op welke criteria heeft deze bedreiging mogelijk effect?
5. Hoe groot is de kans dat zoiets gebeurt?

1. Wat zijn de aanwezige kansen voor het project?
2. Waardoor ontstaat deze kans? / Hoe kan deze kans werkelijkheid worden?
3. Waarom vormt dit een kans voor het project?
4. Op welke criteria heeft deze kans mogelijk effect?
5. Hoe groot is de kans dat zoiets gebeurt?

B.1.4 Determination of potential interviewees

Alignment of the developed interview questions questions and the interviewees is a logic but difficult process, since the interviewees should be capable to answer the questions. As the MR&R challenges are presumed to occur on various institutional levels, it is preferred to gain empirical insights of MR&R challenges on strategic, program and asset levels within an organization. With the help of the supervisors, the colleagues at Rijkswaterstaat and fellow students working at other public organizations, these persons involved in MR&R challenges are intended to be found.

B.1.5 Approaching strategy

The to-be interviewed persons are approached with an introduction of the research and the purpose of the interview. By linking their personal area of expertise to the research, the intention is to trigger the interviewees to accept the invitation, as they hopefully see the added value of their contribution. After an interviewee has accepted the invitation, the set-up of the interview is sent together with a proposed date and time of the interview.

B.1.6 Execution of the interviews

Before the interview starts, the interviewee is asked to grant permission to record the interview. This will create the opportunity to focus on the conversation instead of writing down the answers.

Since the interviews are of an exploratory nature, the created interview questions function as a solid basis of the semi-structured interviews. During the interview, answers of the interviewees may lead to new questions which are not developed in advance. Instead of a threat, this is seen as an opportunity as practitioners may have additional insights related to the present complexities or opportunities to deal with them, which are not identified before, based on scientific literature. These outcomes may lead to new insights which can be highly valuable for the content of this research.

After all the questions are answered, (if applicable) the interviewee is asked to provide present documentation or presentations related to the discussed MR&R challenge. Since they are involved with the challenge on a daily base, the chance to gather relevant documentation is highest by asking them. These documents will be the opportunity to gather facts and figures of the MR&R challenges, to support the case analysis (as presented in chapter 3 and Appendix D).

B.1.7 Processing the interviews

After the interviews, the recordings or made notes (when recording was not allowed or possible) are evaluated. First, the provided answers are structured according to the identified theoretical background. The answers are reflected to the identified complexities and based on the provided answers, potential additions or are also determined. Altogether, this will shape the identified complexities, together with case related examples as presented in chapter 4.

Next to the overview of the complexities, the discussed ways the different organizations deal with their MR&R challenge are structured. The different FED process designs are compared, together with the reasons behind the decisions which resulted in these FED processes. Patterns are intended to be found, which jointly shape the dilemmas related to the design the FED process. These insights will be combined and in the end, result in the decision-making framework as presented in chapter 5.

B.1.8 Linking the outcomes to the research questions

Jointly, the identified complexities throughout the interviews, in addition to the provided documentation and scientific literature, will lead to answers on the developed research questions. By relating made conclusions to the outcomes of the interviews, the link between the research questions and the held interviews is intended to be created and clarified.

B.2 RESULTS OF THE INTERVIEWS

In this section, the outcomes of the interviews will be discussed. These outcomes will be presented in way, so they are able to trace back, based on the made statements and drawn conclusions in the body of research. Explanation of the results will be done by first providing an overview of the interviewees, followed by the findings from the semi-structured exploratory interviews. The findings are presented per case.

	Code	Organization	Function	Involved cases	Date of interview
1	RI1	Rijkswaterstaat	Portfolio Manager	VenR	23-09-2019
2	RI2	Rijkswaterstaat	Program Manager	VenR, KARGO	22-11-2019
3	RI3	Rijkswaterstaat	Head of Department Procurement and Contracting	VenR	10-12-2019
4	AI1	Municipality of Amsterdam	Technical Advisor	PBK	01-11-2019
5	AI2	Municipality of Amsterdam	Member of Program Board	PBK	18-11-2019
6	AI3	Municipality of Amsterdam	Manager Programming Replacements	PBK	18-11-2019
7	NH1	Province of North-Holland	Program Manager	PMO	25-11-2019
8	NH2	Province of North-Holland	Program Manager	PMO	25-11-2019
9	TU1	Delft University of Technology Water Board of Delfland	PhD Candidate	-	09-09-2019
10	TU2	Delft University of Technology	Associate Professor Public Commissioning	-	19-09-2019

Table B.1: Interviewees

B.2.1 Interviewees

Below, an overview of the interviewees is provided which took part in the exploratory interviews to support the individual and comparative case analysis:

B.2.2 Vervanging en Renovatie Opgave - Rijkswaterstaat

Interviewee RI1

Interviewee RI1 is a Portfolio Manager operating in the West Netherlands South regional division of Rijkswaterstaat. At the time of the interview, the interviewee was involved in the VenR challenge as the Portfolio Manager of a cluster of nine tunnel MR&R projects, which was currently in the preparatory FED phase. These tunnels currently operate with outdated operation technique, the so-called: Tunnel Technical Installations (read: TTI's). During the interview, the following challenges related to VenR were mentioned:

- **Requirements - Conflicting requirements:** During the FED of the involved nine tunnels, a lot of requirements play a role at the same time. Since the tunnels are all located in the Province of South-Holland, MR&R interventions in one tunnel will affect the accessibility of the other tunnels and the region itself. Next to accessibility, requirements like safety and sustainability also play an important role. Tunnels are known for their high safety standards and significant energy consumption during the operation. Therefore, the FED phase is used to find sufficient solutions to realize these (public) requirements. In addition to the content of the nine tunnels, the projects are part of the VenR challenge, which is also accompanied by organizational requirements which aim to improve organizational procedures. Since these requirements may mutually conflict, alignment and configuration of executable projects in a fit-for-purpose manner which meets both the regional and organizational requirements is not a matter of course. It was concluded that both the amount and the variety of requirements complicate the FED process to a great extent, as these all have to be taken into account while preparing the projects.

- **Asset conditions - Need of certain expertise & Resource allocation- Composition of teams:** In line with the previously made statement regarding the (technical) complexity of tunnels, the need for certain expertise within Rijkswaterstaat during the FED of its VenR challenge is present as well. While every project team needs technical, financial, controlling, contracting and legal experts (the so-called Integrated Project Management teams), and the VenR challenge consists of 40 projects, it is a simple calculation regarding the demand of human resources and related skills. However, as the MR&R works in the nine tunnels show great similarities, it was decided to carry out the FED of nine tunnels with one team, instead of nine teams. This significantly reduces the absolute need for human resources and skills, as the FED is carried out by one team.

- **Resource allocation - Composition of teams:** An other important aspect related to human resources, is the necessary time to set up (IPM) teams. Finding available employees to fill the vacant posts in a project team can sometimes take longer than expected. With the current rise of MR&R projects within the VenR challenge, the interviewee expected an even larger issue with the staffing of teams, as the demand for certain skills and expertise increases significantly in a relatively short time-frame. The portfolio manager was somehow lucky, as a team finished a tunnel projects just before the start of the FED of these 9 tunnels, so all involved employees could easily be shifted to a new project. For other VenR projects, the interviewee however predicted larger difficulties regarding the staffing of the teams.

- **Configuration options - Variety of configuration options:** In contrast to the other assets within the VenR challenge, the interviewee decided to merge nine MR&R-needy tunnels into one project. The reason behind this decision, was explained as follows: *"I have nine tunnels with more or less the same MR&R challenge within my region I am operating in. Why would I set up nine different project teams, when one team can do the job as well. This team was even already available, as a comparable project just finished. Thereby, the Dutch market is characterized by just three or four contractors who have the correct specifications to do such specialized work like the renewal of the TTI's. This reduced the complexity of later on procurement, as only four contractors are able to do the work. As the remaining technical lifetime of the current installations is running out, I need to act quickly. Merger of the nine tunnels into one project was therefore a no-brainer for me."* So by having nine relatively similar MR&R-needy assets, which are all in the proximity of each other (within the same West Netherlands South Region of Rijkswaterstaat) and the presence of an up and running project team, made the interviewee decide to merge the assets into on project during step 2 (the regional analysis) of the FED procedure, as shown in figure A.3. This decision to merge nine tunnels into one project, is however uncommon for the VenR process, as this is the only know case where such a cluster is made. The decision of the interviewee to go off the beaten track was therefore accompanied by a suggestion for the VenR team to seek such asset transcending configurations in future Tranches.

- **Composition - Consciously including or excluding elements:** Tunnels are complex asset due to their underground location, complex operation systems and high safety standards. In the Netherlands, building and operating tunnels is therefore seen as a kind of craft and related expertise which is owned by just a few contractors. Now the TTI's of nine tunnels have to be renewed, the portfolio manager an its team there will be only four or five contractors which would be capable and certified to execute the renewal works. Instead of investigating the exact scope of the MR&R works, the team of the Portfolio Manager decided to leave this responsibility with the contractors, as part of their contract bids. Determining this during the FED would be useless, since the expertise is simply not present at Rijkswaterstaat and would take a significant amount of time. Using the expertise and creativity of the contractors is used, by requesting this knowledge in consecutive project phases.

- **Scope - Increased scope leads to more interrelations::** By merging all 40 projects of VenR into one Tranche, the interviewee mentioned that the entire VenR challenge is becoming somewhat chaotic and unforeseeable. As being responsible for one of the 40 projects within Tranche 4, the interviewee mentioned that he had the feeling that he was just one of the 40 projects, which all demanded a common set of resources. The benefit of merging all 40 projects into Tranche 4, with a variety of different assets, the interviewee questioned the added value of this decision. *As these benefits of having a portfolio of 40 MR&R projects are not sought and used, and lead to more complex decision-making regarding the development of the projects, why not carry out the MR&R projects individually or in smaller proportions? Probably, it would be more beneficial if the Tranches were separated according to a region or to a specific kind of asset. .*

- **Coordination - Including VenR in the regular workflow** The interviewee mentioned a significant issue regarding the planning of the VenR activities among "his" nine tunnels and also the other projects within VenR and Rijkswaterstaat as a whole. Since these tunnels are not the only (VenR) projects in the region, the effects of MR&R works to the tunnels will logically affect the accessibility of the surrounding regions. Currently, the first VenR project which is ready to move from the FED phase to the execution phase, is served first. The interviewee explains the issue

as follows: *"The VenR execution planning works on a first-come-first-serve basis, the project team which hands in the final execution plans first, can start first. This does not encounter any interrelations with other projects (outside the VenR scope), which may lead to severe congestion in the future. If I would simultaneously execute MR&R works to all tunnels within my portfolio, it would lead to severe traffic infarcts in the South-Holland region. Execution of MR&R works and related planning need nation-wide coordination, which is currently not the case."* The current first-come-first-served approach is therefore questionable, as coordination of the related VenR projects may be better from an organizational or regional overarching perspective. Despite the intention to include VenR in the current workflow, the integrated planning of the project creates a complex situation regarding the coordination of the VenR projects.

Interviewee RI2

Interviewee RI2 was part of the 'intaketeam', which was responsible for planning, executing and reporting all intakes for the MR&R-needy assets of Tranche 4 in the VenR case. These intakes took place at the beginning of step 4 of the VenR process, as visualized in figure A.3. The idea of these intakes was to gather a more detailed view on the assets which are part of Tranche 4 and their related MR&R demand. This was seen as a potential solutions to deal with the delays which were present during the previoous Tranches during the FED and execution phase. By doing this for all assets which were part of Tranche 4, the organization aimed to get a better overview of the challenges which lay ahead and to prepare the execution of Tranche 4 in a fit-for-purpose manner. During the interview, the following challenges were identified:

- **Resource allocation - Composition of teams :** Purpose of these intakes was to create insight in the scope of the work, research demands, requirements of the surroundings, necessary knowledge and expertise and potential bottlenecks. A direct consequence of these intakes is a assumption of the necessary (human) resources which will be necessary for the entire VenR challenge. At the end of the intakes, when all results were merged it became obvious that Tranche 4 of the VenR challenge demanded a significant share of the nationally and regionally operating divisions. Since these necessary (human) resources are sometimes not present, development of the FED and the consecutive execution of the MR&R interventions may face delays.

- **Composition - Consciously including or excluding elements:** In the light of the VenR intakes, gathering asset information in detail up front was determined to be costly and time consuming during this stage of the FED process. However, absence of data confirming the exact state and related technical end of an asset's lifetime causes a risk with a related uncertainty in terms of decision making on the design alternatives and configuration options. To get an improved overview of the MR&R related demands among the entire Tranche 4, it was decided to incorporate the intakes in the process, which was previously absent in the other Tranches.

- **Scope - Increased scope leads to more interrelations:** Execution of the FED process is done in both an integrated manner, as well as an individual asset manner. These intakes are standardized to provide an overview of the conditions and related MR&R demand of all assets in the Tranche. Subsequently, all (elements of) assets within this Tranche go though an individual evaluation of sufficient design alternatives. This results in a preferred design alternative for one certain asset within the entire Tranche of 40 projects. The benefit of executing the standardized intakes for an entire Tranche without seeking clustering opportunities within this portfolio is questionable. As a consequence of merging all MR&R-needy assets in a Tranche, simultaneously a severe amount of considerations have to be made related to for example resource allocation and consequences of execution plans. The interviewee however places question marks at the effectiveness of this decision, as the benefits of increasing the scope of the decision-making and related activities are simply not evident.

- **Sequence - Options to postpone crucial activities:** In the light of the intakes, the interviewee mentioned that the timing of the intakes would potentially have more value and are easier to perform, if they are executed during step 2 (the region analysis) instead of during step 4 (the scope phase). During the region analysis, the regional division of Rijkswaterstaat indicates (globally) the current MR&R demand of the region. Together with this analysis, it would be easier and more

efficient to carry out the intakes immediately, since the information regarding the MR&R demand of the assets is often with the asset managers operating on a regional level. Instead of involving the nation-wide divisions, the regions could simply fill in the standardized intake forms and provide them to the coordinating divisions within Rijkswaterstaat. This would save effort and time, since all these activities are currently carried out jointly with the national and regional divisions.

Interviewee RI3

Interviewee RI3 is Head of the Procurement and Contracting department of Rijkswaterstaat. Thereby, he is part of the team which determines the procurement strategy of the entire VenR challenge, and is therefore closely related to the FED of VenR. During the interview, the following challenges related to VenR were mentioned:

- **Requirements - Amount of requirements:** Currently, during the FED phase of the VenR challenge, the extent (amount of assets involved) of the fourth Tranche results in complexities while trying to move from the FED phase to more detailed execution plans. As the projects within VenR Tranche 4 are interrelated due to their merger in this Tranche, the total amount of present requirements which have to be considered simultaneously is enormous. Since the shift from FED to execution is currently prevented due to the magnitude of the Tranche, the chosen approach may be reconsidered as a clear difference among the requirements is lacking. This results in a situation where a lot of requirements have to be considered at the same time, which complicated the decision-making process. The interviewee therefore suggested a guided trade-off, which would state certain preferences among the requirements to speed up the decision-making process during the FED phase.

- **Scope - Increased scope leads to more interrelations:** The interviewee also mentioned the increased opportunities which arise due to the merger of all 40 projects in one Tranche. Currently, after step 4 of the FED process, every project has an individual team and related project plans. However, given the amount of assets in Tranche 4, the opportunities to merge certain projects into a multi-project environment is created. By executing multiple projects within the scope of one larger project, portfolio or program, the necessary amount of project teams decreases. Thereby, having a bundle of multiple projects, creates the opportunity to implement innovations on a project transcending basis. This creates the opportunity to spread out the investments of the innovations over a larger amount of projects, which makes the innovation within the projects economically feasible.

- **Configuration methods - Variety of configuration options:** Having 40 projects within Tranche 4 of the VenR challenge creates an overview of the MR&R need within Rijkswaterstaat. However, merger of all these 40 projects into a Tranche, which can be seen as a somehow enclosed environment also create complications. These complications arise due to the effect of decision-making on one asset on the others. Multiple configuration options emerges, which results in more trade-offs which have to be made, in comparison to a one-asset-one-project approach and not merging these assets into a certain Tranche.

- **Configuration methods - Necessary effort to find configurations:** In line with the previously discussed complexity regarding the size of the VenR challenge, the necessary effort and time to find potential configurations increases accordingly. Given the presence of 40 projects in one Tranche, the opportunities for potential configurations are enormous. However, finding these configurations seems in practice often more complicated than one may perceive. For assets which are in a critical state, due to severe deterioration rates, the effort it takes to find potential configuration with other assets is simply not present. Immediate action has to be taken to minimize the necessary time before the MR&R interventions can take place.

- **Composition - Using a stage-gate system:** The FED procedure consist of two formal decision-making moments, to challenge the development of the VenR challenge and its involved projects. The first moment checks whether an asset meets the requirements to be included in a new Tranche. If assets meet the exit criteria, they are excluded from the consecutive FED steps. Second decision-making moment evaluates the chosen configuration options. Including these formal

decision-making gates creates the opportunity to have a critical view on the rationale to pursue the development to next phase in the development of the projects.

- **Sequence - Premature convergence leading to path dependency:** Despite the content of VenR Tranche 4 and the amount of assets involved, the interviewee mentioned the effect of the chosen FED procedure on the opportunity to use the present configuration opportunities. Step 4 of the FED procedure consist of the scope phase, where the exact MR&R demand is determined. After step 5, a decision is made regarding the preferred alternative which determines the scope of the MR&R interventions of one asset. Since the decisions are made for one asset, the opportunity to merge multiple assets into one project, portfolio or program is absent due to the chosen FED process design. Therefore, the chosen FED procedure makes the process path dependent.

- **Coordination - Including VenR in the regular workflow:** The share of VenR projects within Rijkswaterstaat is increasing and expected to grow even more in the future. Next to the development of greenfield projects and maintenance projects, which are already embedded in the organization for a long time, the MR&R projects lack such an standardized working procedure. To do so, the organization decided to incorporate the VenR activities within the current organizational structure. Given the (financial) size and location of the project, a project is dedicated to a certain division in the organization. The interviewee mentioned that reason behind this decision results from the idea that like greenfield and maintenance projects, MR&R (or VenR-like) projects will also become a regular part of the organizational activities. Including them in the existing organizational structures, therefore intends to create similar standardization benefits regarding the execution of MR&R projects. Thereby, the interviewee elaborated on the deliberate decision to not create a separate division or program to deal with the VenR challenge: *Programs, within Rijkswaterstaat, are often a cluster of multiple projects which are share a corresponding objective. Take for example, Room for the River, a program which had the objective to prevent flooding of the Rivers in the Netherlands. The objective was clear: create room for the rivers by improving the drainage and storage capacity. After this is done, the objective is reached and the program is terminated. Now both VenR and Room for the River consisted a multitude of individual projects. However, the big difference is that the Room for the River program is finished when the projects within the program are completed. This is not the case with the VenR challenge, as MR&R projects will continue infinitely. Therefore, it is decided to include VenR in the current organizational structure, and not design it as a program.* Creation of a program would create a separate 'island' within the organization. Which collaborates with the rest of the organization to a limited extent, due to the specific purpose and related objectives of the program.

- **Adaptivity - Revising the FED process for a new Tranche:** Since the VenR challenge creates a relatively new flow of projects within Rijkswaterstaat, the FED procedure is something that develops over time. Based on the insights of Tranche 1 until 3, decision-makers decided to adjust the procedure, by for example introducing the intakes (as discussed with interviewee RI2). Lessons learned from the previous Tranches therefore functions as input for the set up of the FED procedure of Tranche 4. Changing the chosen FED process therefore shows the presence of adaptivity in the VenR challenge. *"Having similarities among the assets in a Tranche and actually merging these assets into a project or program can reduce the need to develop individual teams for each asset, prepare and go trough the tender procedure only once for a multitude of assets and manage impacts of traffic nuisance in a better way."* Creating the opportunity to evaluate and revise (parts of the) FED process, therefore creates opportunities to perform more and more in a fit-for-purpose manner. However, changing the FED procedure for Tranche 4 also led to some difficulties, as the employees who are involved in the VenR challenge had to change their way of working, which led to some difficulties with the implementation of the earlier mentioned intakes.

B.2.3 KARGO - Rijkswaterstaat

Interviewee RI2

Next to VenR, interviewee RI2 was also involved in the KARGO case as a program manager. Since KARGO consisted of eight steel arched bridges crossing the Amsterdam-Rhine Canal, managing the

program involved significant complexities. During the interview, the following challenges related to KARGO were mentioned:

- **Asset conditions - Need for expertise:** During the FED of the KARGO program, Rijkswaterstaat had the idea that given the current knowledge on the conditions of the asset, seven of the eight bridges could be renewed and only one had to be replaced. However, the contractors had the freedom within their contract bids, to determine themselves how many bridges had to be renewed and replaced, based on their estimations and calculations. This resulted in an overview, as presented in table A.4. The contractor with the highest score, based on the EMVI-criteria, won the tender and got the contract. However, the winning bid and related renewal / replacement ratio had to be adjusted once the contractor started with the preparatory execution works. During these preparatory works, the contractor detected additional defects which were not indicated before. Based on these new insights, the decisions to either renew or replace a bridge were adjusted. To emphasize the complexity, the interviewee mentioned the following aspect: *"It is extremely hard to tell what is inside a bridge before you open it up. Sometimes you think that you know what to expect, but the reality often appears to be completely different. Deterioration of certain bridge components was in some cases way worse than expected. This does not say that the maintenance inspections were carried out inappropriately. On the outside it is simply hard to tell what is on the inside.* The need for certain expertise while determining what exactly has to be done in MR&R challenges is therefore inevitable.

- **Resource allocation - Composition of teams:** By merging the renewal and replacement activities of eight bridges into one program, only one team was necessary to compose in order to manage the program. Instead of eight separate teams, necessary knowledge was merged in one team for all of the eight bridges. The interviewee mentioned that this reduced the demand of human resources to a significant amount and created the opportunities to merge expertise from several divisions into one team. Traditionally, maintenance activities are all coordinated by the regions. Asset managers work in their own domain and are used to carry out their activities with no or little collaboration with other regions. As the demographic conditions of the KARGO program covered two Rijkswaterstaat regions, collaboration was demanded. The decision to merge and coordinate all activities from one location, required new forms of collaboration. Naturally, representative of one region had there prime focus on their own area, instead of the program in general. Alignment of interest and joining forces demanded therefore a new mindset and took some time to develop. As these regions normally do not cooperate on a daily base, attention had to be paid to the set up of the team and alignment of objectives. In practice, this seemed to take more time then expected and therefore increase the complexity of the program from an organizational perspective

- **Resource allocation - Financial flexibility:** During the preparation of the KARGO program, Rijkswaterstaat had developed a fixed price cap given their perspective on the scope of the program. Interested contractors had to adjust their bids to this price cap, otherwise their bids would be invalid. In line with the earlier mentioned need of certain expertise, the scope of the KARGO program changed significantly after the contract reward as the MR&R demand of some bridges differed from the presumption. To emphasize the complexity, the interviewee provided the following example: *"Calculations of reinforcements to the Breukelerbridge would result in an entire additional steel bow structure on top of the existing structure, to comply to the present laws and regulations regarding bridge safety. The costs of this renewal interventions compared to the additional technical life span did not outweigh the alternative of replacing the entire bridge. Therefore, the contractor and client decided to go for a replacement instead of a renewal."* As a consequence of these adjustments, the final costs of KARGO were 38% higher than predicted. However, the interviewee emphasized that within MR&R challenges, the room for financial flexibility should be way higher, compared to greenfield project as the scope is simply way harder to determine up front.

- **Configuration methods - Diversity of configuration grounds:** Since the interviewee was both involved in KARGO and VenR, the opportunity to compare both FED procedures create an interesting insight in the diversity of grounds to base a configuration on. The bridges which were part of the KARGO program were already composed as a cluster of eight, before extensive condition

assessments were executed. The merger of the bridges were done, based on a corresponding: size (span), material (steel), location (crossing the Amsterdam Rhine Canal) and demand to heighten the bridge (due to increased inland cargo shipping heights). Thereby, the interviewee mentioned that the merger of eight bridges into one program was also chosen, based on the purposed to create a learning-by-doing effect, create opportunities for integrated risk management and create economies of scale by 'buying' multiple relatively similar bridges at the same time from the same contractor.

- **Composition - Consciously including or excluding elements:** As Rijkswaterstaat and the involved team were not sure about the exact MR&R demands of all bridges, they decided to postpone the detailed condition assessments to a moment after the FED. The configuration of the program was based on other conditions, like the earlier mentioned material, location and so on. As it would take significant time and effort to assess the actual technical conditions of the assets, a conscious decision was made to postpone this effort to a later moment and to exclude it from the FED procedure.

- **Sequence - Premature convergence leading to path dependency:** Involvement of the interviewee in both VenR and KARGO cases, also created the opportunity to compare review the FED process design. Where VenR follows a process which declines the opportunity to find asset transcending benefits and potential clusters of assets, the FED of KARGO actually had this opportunity. By first reflecting on the MR&R-needy assets and their location, material and so on and making a decision on the related configuration afterwards, it was possible to configure KARGO as a program consisting of eight bridges. Since VenR does not have this option, it can be said that premature convergence influences the opportunity to create better (or more fit-for-purpose) outcomes, as it is dependent on previously made decisions. The room to find such configurations of multiple assets therefore needs a FED process which creates this room.

- **Scope - Increased scope leads to more interrelations:** The interviewee mentioned that increasing the scope of a project or program from one to eight bridges naturally requires more effort to coordinate the whole. Instead of one surrounding environment, eight surroundings environments had to kept satisfied, the planning of eight instead of one bridge had to be made, updated and coordinated, communication of potential nuisance for road and waterway users had to be done eight times, and so on. However, next to absolute increase of necessary activities which had to be managed and the increased amount of interrelations, the interviewee mentioned that the ability to learn and repeat certain activities created significant benefits which would probably not achieved if all projects would be managed individually. Therefore, increasing the scope to eight bridges was in the opinion of the interviewee easier compared to managing and executing the MR&R interventions in eight separate projects.

- **Coordination - Creation of a program**: The coordination of the eight bridge renewals and replacements was done by one team, consisting of two regional divisions (Middle Netherlands and West Netherlands North) and the nation-wide GPO division. Creation of a program and coordinating it in such way was both challenging and created opportunities at the same time. The replacement of the first two bridges was challenging for the entire team and let to a spending of 80% of the entire contingency budget. However, as the entire team was learning from the experiences of replacing bridges, it became more of a routine. This resulted in very limited risks and a lot of confidence for the entire team while replacing the last couple of bridges. Learning from the previous replacement interventions was therefore mentioned as a major advantage for the progress of the execution of the KARGO program. The interviewee mentioned that the size of the KARGO program did not actually led to the complexity or coordination difficulties, but it was related to MR&R interventions in general. In line with the earlier mentioned aspect related to the need of expertise in MR&R projects, KARGO faced most complexities due to the compelxity of the MR&R interventions itself.

B.2.4 Programma Bruggen en Kademuren - Municipality of Amsterdam

Interviewee AI1

Interviewee AI1 is involved in the 'Programma Bruggen en Kademuren' as a technical advisor. In his role, the supports the department within the Program, which is responsibile for Safety, Knowledge and Advice, as shown in figure A.8. His role was mainly focused on providing advice whether temporary constructions at certain critical locations had to be placed or other mitigating measures had to be taken in order to safeguard the safety of the bridges, quay walls and their surroundings. During the interview, the following challenges related to PBK were mentioned:

- **Requirements - Conflicting requirements:** As a technical advisor focusing on the conditions of the assets within the PBK, the main requirements he and his teams were focusing on was safety. The interviewee mentioned the poor condition of a significant amount of assets within the Municipality of Amsterdam. After technical condition assessments were carried out about engineering firms, the team had to formulate an advice to the board regarding the appropriate measures which could and should be taken to maintain the safety of the asset and its surroundings. However, closing off an asset due to its poor condition is something which would significantly influence the accessibility of the city. Despite the risk of severe damage and safety issues, the trade-off between safety and accessibility remains a very complicated one for the Municipality.

- **Asset conditions - Detail of condition assessment:** In line with the earlier mentioned poor condition of some assets, the Municipality needs to carry out rather detailed condition assessments on the assets of which is known or suggested that they are in a poor condition. By executing detailed condition assessments, an improved insight on the remaining technical life span of an asset is intended to be created. However, next to the identification of the technical life span of an asset, additional conditions are also determined, like: traffic flows, purpose, location and material of the asset and proximity to residential areas. Since safety is not the only requirement which plays an important role in the determination of MR&R interventions, the interviewee mentioned the diversity of the condition assessment while investigating an asset.

- **Design alternatives - Varying impact of design alternatives:** The interviewee mentioned that, in contrast to other public organizations, the Municipality of Amsterdam faces a rather different situation. Determination of the most appropriate design alternative, in other words: determining whether an asset is going to be maintained, renewed or replaced, in most of the cases leads to a decision for a replacement. The interviewee mentioned two reasons for this: (1) determination of the exact conditions and options to renew an asset often take so much time and effort, that the replacement alternative is simply preferred. (2) As renewal often increases the technical life span of an asset with a decade or two, replacement is often accompanied by an estimated technical life span between the 50 and 100 years. This means, that the surroundings in the case of renewal, would face MR&R interventions and the related nuisance to a larger degree over the coming years. Since the magnitude of the MR&R challenge in Amsterdam is so large, it is often decided to prefer replacement over renewal, even if replacement is not necessary.

- **Configuration methods - Variety of configuration options:** Given the size of the PBK, the amount of configuration options is infinite. The interviewee mentioned that given the amount of assets which probably need a MR&R intervention in the coming decade, a wide variety of configuration options is present. The interviewee mentioned the opportunity to merge all bridges crossing a (part of a) canal, a certain busy route, having a certain size, a corresponding material and so on. Given the amount of configuration options, decision-making regarding the final configurations was even more complicated, as the potential configurations all have their pro's and con's, given the present set of requirements.

Interviewee AI2

Interviewee AI2 is part of the Program Board of the 'Programma Bruggen en Kademuren' and as a director responsible for the programming and acceleration of the execution. Since the interviewee is involved in the daily decision-making process regarding the design of the FED process of the PBK, the

insights of the interview shed a comprehensive light on the challenges which occur within the PBK. During the interview, the following challenges related to VenR were mentioned:

- **Requirements - Influence of organizational strategy:** The Board of Mayor and Aldermen of the Municipality of Amsterdam decided that the best way to deal with the current MR&R challenge was through the creation of a program, called: Programma Bruggen en Kademuren. Thereby, the PBK should not only focus on the reducing of deferred maintenance and executing MR&R works, but also implementing other objectives of the Municipality, like: Underground waste collection, waste collection over water and creation a car-free city. Since these objectives are imposed by the Board of Mayor and Alderman, the organizational strategy seems to have significant influence on the present requirements which have to be considered during the FED of the PBK.

- **Requirements - Amount of requirements:** The interviewee mentioned that the city of Amsterdam is unique in its diversity of stakeholders and their related requirements. While begin the capital of the Netherlands, with an infrastructure which dates back from the ancient times and with enormous amounts of infrastructure users, renewing and replacing bridges and quay walls is a hell of a challenge. Given the amount of present requirements which have to be considered while making a planning for the execution of MR&R intervention, the Municipality faces and extremely complex challenge.

- **Resources - Financial flexibility:** Instead of requesting a budget for every MR&R intervention within the PBK, the Municipality decided to attribute multiple budget reservations for several purposes, like: execution of replacement works and related research, incidents, enforcement, monitoring and innovation investments. By having certain reservations available, a certain level of freedom is present to invest significant amounts of money in aspects which actually need it. This creates a situation where necessary investments can be made, without requesting a budget for every single matter. Thereby, this flexibility creates a situation where the Municipality can operate much more quickly, as investments can be made from the present reservations, provided that the imposed investment meets the purpose of the reservation.

- **Design alternatives - Varying impact of design alternatives:** In line with the made statement by Interviewee AI1, the interviewee mentioned that within the PBK the Municipality will most likely decide to choose for replacement over renewal. The time, effort and nuisance which can be saved by replacing and asset instead of renewing it simply outweighs the necessary investment which has to be made at this point. The magnitude of the necessary MR&R interventions simply demands a high MR&R ratio of multiple bridges and kilometer of quay walls every year.

- **Coordination - Creation of a program:** The Municipality of Amsterdam decided that to coordinating the entire MR&R challenge of the Municipality, a separate program / division within the Municipality was created to deal with the challenge. The program is staffed with an own board, financing structure and adjusted working procedures. The Program Board of the PBK is directly linked to the executive divisions of the program, which keeps the distance management and execution of the MR&R activities small. The interviewee pinpointed that given the current magnitude of the MR&R challenge within the Municipality of Amsterdam, creation of a program was considered to be most optimal way to plan, coordinate and execute the necessary MR&R interventions. He thereby acknowledges that the magnitude of the PBK creates a significant challenge for the Program Board and the involved staff, but the challenge simply demands such a large-scale approach to increase the speed of necessary MR&R interventions.

Interviewee AI3

Interviewee AI3 is the Manager responsible for the programming of the replacement works within the PBK, and part of the team which is managed by interviewee AI2. As a Manager Programming Replacements, the interviewee is involved in making the planning of the MR&R interventions for the coming years. Since the PBK encounters 850 bridges and 200 kilometers of quay wall which need to be renewed or replaced in the nearby future, the complexity of this challenge is evident. During the interview, the following challenges related to PBK were mentioned:

- **Requirements - Conflicting requirements:** Since the interviewee is responsible for the programming of the MR&R activities for the coming years, he logically has to encounter a lot of requirements which have to be considered. As the conditions of some assets on vital locations within the infrastructure network of Amsterdam is so bad, temporary emergency constructions are places or other mitigating measures are placed, to reduce further deterioration of the assets. These mitigating measures are necessary, as some assets are so important to infrastructure network, it is considered impossible to fully close these assets off, even when the condition of the asset is really poor. This highlights the continuous dilemma the interviewee is facing due the the presence of numerous important requirements at the same time.

- **Design alternatives - Varying impact of design alternatives:** In line with the other two interviewees, the interviewee mentioned that replacement of an asset is often favored compared to renewing an asset. The interviewee further elaborated on the situation as follows: *Sometimes, a situation may occur where an asset which is in a really poor condition is surrounded by an asset which does not need MR&R intervention. In this situation, an approximation of the remaining lifetime of the surrounding assets is made. If the surrounding asset has a remaining technical lifetime of 25 years or less, it may be decided to include the asset in the planned MR&R intervention of the asset which is in a rather poor condition which needs immediate MR&R intervention. Including the assets which would still suffice for the coming 25 years, results in a situation where a specific area hopefully does not need any MR&R interventions for the coming 50-100 years. As the impact of MR&R interventions on the surroundings has such a significant impact, the decision to replace assets which are not in immediate need of a MR&R intervention is still made. (..) I won't call this decision to replace assets which are still in good shape capital destruction, rather anticipated capital investments.*

- **Scope - Increased scope leads to more interrelations:** While being responsible for the programming and acceleration of the MR&R activities, the interviewee mentioned the current struggle he and the entire PBK faces with the magnitude of the program. The Municipality aims to to upgrade the state of all MR&R-needy assets as good as possible. As good as possible in this sense, refers to a minimal nuisance to the surroundings and the users of the infrastructure of Amsterdam. However, the magnitude of VenR results in a situation where a lot of MR&R-needy assets are in close proximity of each other. Closing of one bridge for replacement works therefore has significant impact on the accessibility and user rates of the surrounding assets. Making a decision regarding the replacement directly affects the other assets, the surroundings and potentially other projects of other stakeholders like public transportation organizations, energy companies and network operators. On the other side, the interviewee mentioned that if every asset would be managed individually, the effects of MR&R interventions would be harder to oversee and therefore lead to unexpected and potentially unwanted surprises.

B.2.5 Provinciaal Meerjarenprogramma Onderhoud - Province of North-Holland

Interviewee NH1

Interviewee NH1 is involved in the 'Provinciaal Meerjarenprogramma Onderhoud' of the Province of North-Holland as the program manager focused on the management strategy and programming. From his role as program mananger, the interviewee is involved in the management of the program as a whole from the role of the Province. During the interview, the following challenges related to the PMO were mentioned:

- **Asset conditions - Need of certain expertise:** With the 'gebiedscontracten' (read: GBC), the Province of North-Holland decided to outsource the low-complexity MR&R activities of the Province in six contracts, spread out over seven regions. Traditionally the Province planned, procured and managed these kind of activities, and the contractors simply carried out the provided MR&R activities. Since the Province acknowledged the inefficiencies of creating a contract for every single MR&R work, like ecological roadside management, de-icing, road surface replacements a new way of working was sought. As these activities are relatively simple from a technical perspective, it was decided to merge all these activities in a contract, where a contractor will be responsible for these activities over a time span of 10 years. The interviewee mentioned that with

this decision, the Province intended to create efficiency improvements, as the contractor has the freedom to plan the MR&R activities themselves, which creates the opportunity to execute them in off-peak moments. Thereby, innovations and standardization benefits were likely to be stimulated, as the contractor has the responsibility to execute the MR&R works in the coming 10 years. By using the expertise of the contractors, the necessary MR&R interventions are to be executed in a way that leads to a significant decrease in effort for the Province and efficiency improvements at the same time, while the contractor has a stable workflow and income for the coming 10 years. The interviewee mentioned this as a win-win situation.

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- **Configuration methods - Diversity of configuration grounds:** In line with the earlier mentioned reasons to enclose all 'low complexity' MR&R activities were based on the intended benefits of: reduced amount of work for the Province. Since all activities which in the past had to be planned, procured and maintained, the contractor in charge is not responsible for all of these activities in the coming 10 years for a certain region. The Province now only has the responsibility to preform spot checks and review proposed plannings of MR&R works within the Province. With this shift of responsibilities, the Province is relieved for such activities for a minimum of ten years. Thereby, outsourcing all these activities over a time span of 10 years creates the ability for the contractor to freely plan and execute the MR&R works at times it suits him best. By having the ability to carry out the activities in off-peak moments, the allocation of resources can be optimized at the contractor, which was intended to create efficiency improvements and lower overall costs of the necessary MR&R activities in the Province. Splitting up the entire Province in seven regions and outsourcing these activities over a time span of 10 years given the discussed intended benefits, are therefore seen as potential grounds to configure a MR&R challenge in this way.

- **Configuration methods - Variety of configuration options:** The interviewee mentioned that the reason to split the Province up into seven regions was mainly based on the demographic division of existing roads and other main infrastructure. The decision to make it seven regions instead of 2 or 20, was due to the intended benefits of having a certain area to execute the MR&R activities. As contractors have to invest in certain machines and so on, it would be inefficient to make 20 investments instead of seven. Thereby, if the region would be split up into to two regions, it would probably too large for the contractors to manage the GBC and all detailed activities appropriately.

- **Scope - Increased scope leads to more interrelations:** Within the GBC, the deliberate decision was made to exclude more complex MR&R activities from the contract. Currently, the scope of the contract is clear for all contractors and delimited to a set of MR&R activities. The interviewee mentioned that, besides the differing demand for certain expertise to carry out other MR&R activities, including more activities would likely decrease the benefits of the chosen GBC. The reason for this would be that the scope of the contract would be so large, that the contractor would probably face manageability issues and potentially issues with prioritizing activities, as th contract would consist of a significant variety of activities which all had to be carried out.

- **Sequence - Options to postpone crucial activities:** Regarding the GBC, the deliberate decision was made to leave all planning and executive responsibilities with the contractors. Within the GBC, it was formulated which activities had to be executed by the contractor, not how it should be done. This room for freedom and creativity was created by not determining this up front. It was therefore deliberately decided to postpone these activities to a phase after the contract rewards, where the contractor could figure out his preferred way of operating and executing the activities which are part of the GCC.

- **Coordination - Creation of a program:** The PMO, or Provinciaal Meerjarenprogramma Onderhoud is a program which leaves most responsibility with the contractors to execute low-complexity MR&R activities over a time span of 10 years. The coordination to oversee all activities is however still with the Province, as they are the client in this program. In the beginning, this asked for a new way of working for the Province, as their role shifted from organizing to overseeing the MR&R activities within the Province. Employees like asset managers which were

traditionally responsible for the coordination of MR&R activities in the Province have to get used to their new role. Instead of coordinating, their current role is more of a supervising and controlling nature. Planning mandate of MR&R activities is still with the Province, which gives the contractors not the full freedom to execute the MR&R activities whenever they want. Thereby, quality assurance is also checked by the Province by conducting spot checks and reviewing quality reports. In this way, the Province is still involved and carries responsibility to a certain extent.The interviewee mentioned this shift as follows: *"In this way, usage of GBC is more like ordering a service like companies have to clean their offices. It is a matter of trust and setting the right requirements in the contract. If these two factors are present, it works perfectly*

- **Adaptivity - Introducing GBC in a phased manner:** Since experience with these kinds of contracts was lacking, the Province decided to introduce the GBC in a phased manner. By doing so, the idea was to work on an trial-and-error basis while learning from past performance. Input from lessons learned of older GBC were used as input for new GBC. Program manager NH1 mentioned that working in an adaptive manner resulted in a situation where the Province can respond in an effective manner to unforeseen circumstances. In advance it is hard to know exactly how to formulate a contract which covers all of the activities a Province wants to outsource in a convenient matter. Rolling out the GBC in a phased matter and adapting the content based on new insights therefore resulted in opportunities to tighten the gap between expectations and outcomes. The older contracts which did not consist of these new insights were adjusted 'on the go', which led to some adjustments in the expenses as these aspects were not part of the first contract. He further deliberated: *"As this was the first time the Province was working with GBC, we accepted that it would not work perfect from the beginning. Therefore, we applied a learning-by-doing approach. After the first GBC was awarded and going on for some time, we found out we forgot to mention some relevant aspects in the tender phase before awarding the contract. These adjustments were included in the the following GBC, so the same issues would not exist in other GBC. Making adjustments to a contract while it is already running is always harder and often more expensive. However, thinking that you can prepare for ev124 additional case information everything and making a perfect contract is a fairy tail. You will always face certain 'grey-areas', but learning from the past makes you more reluctant to these unwanted and uncertain aspects."*

Interviewee NH2

During the interview, interviewee NH2 was in a transition period to become the successor of interviewee NH1 as the program manager, responsible for the management strategy and programming. In the past, the interviewee gained experience in program management in various industries. Despite being the program manager of the PMO for a relatively short time, the following challenges related to PMO were mentioned:

- **Requirements - Influence of organizational strategy:** The interviewee mentioned that the Province of North-Holland has faced an organizational shift which aims to reduce the organizational effort in the management of MR&R activities. Instead of being in charge of every single little projects, more responsibility is intended to be outsourced, to reduce the workload for the Province. Since the decision was made on an organizational level, to work with 'gebiedscontracten', the program managers in charge had to find a way to implement this new way of working in an appropriate manner. In this way, the organizational strategy strongly influences the present way of working for the PMO.
- **Asset conditions - Need of certain expertise:** Thereby, the remaining MR&R activities which require more technical expertise and exceed a budgetary limit of €5 million, are not part of the GBC. Since the necessary expertise to renew or replace a bridge with a span of 50 meters differs significantly from the replacement of road surfaces or carrying out de-icing activities, it was decided to exclude such activities from the GBC. The necessary expertise to carry out these more complex MR&R activities simply require a different kind of expertise which is not required for the execution of the GBC. Therefore, it was decided to exclude these more (technically) complex MR&R interventions from the GBC.
- **Resource allocation - Financial flexibility:** To execute the PMO, the Province of North-Holland made certain reservations for the program. All GBC consist of yearly remunerations based on

the present contracts. Thereby, a certain reservation is made for MR&R interventions which do not exceed the €5 million boundary. These activities can be carried out by the present contractor which is in charge in a certain region, but is not part of the contractual arrangement. As the Province supports the contractors to come up with potential MR&R interventions which they detect within their region, the budget reservations can be used to execute these MR&R activities. The interviewee explained that this provides the necessary freedom to spend the amount which is necessary for the activities. If the budget would be limited to a fixed amount in advance, it could be that this would be insufficient for the necessary MR&R works to upgrade the state of an asset. Yearly actualisation of the reservations in the overall budget, assures there is also a budget available for all projects.

- **Sequence - Premature convergence leading to path dependency:** Since the Province of North-Holland does not formulate the exact way the MR&R have to executed and when, the contractors have a certain freedom to determine how they want to do their work. By providing this freedom, the interviewee mentioned that the innovative capacity of the contractors is used, which is leading to significant efficiency improvements. Most important is that the necessary MR&R works are executed well. The timing for example, is less relevant to the Province, as long as the contractual agreements are fulfilled.

B.2.6 Delft University of Technology

Interviewee TU1

Interviewee TU1 is a PhD Candidate within the public commissioning chair both working at the Delft University of Technology and the Water Board Delfland. The interview was mainly exploratory and to provide an improved understanding about the way the Water Board Delfland deals with their MR&R challenge. However, the PhD of the interviewee was not directly related to MR&R challenges, but more focused on procurement and contracting. It was mentioned that the Water Board Delfland does operate in a rather project based way to deal with their MR&R-needy assets. If an asset is reaching the end of its technical lifetime, the asset managers determine the scope of the MR&R project. After this is done, it is shifted to the procurement and contracting department, which try to find an appropriate contractor to execute the MR&R interventions. The interviewee thereby mentioned, that the separate divisions cooperate to a limited degree. Thereby, a portfolio-based or program-based approach is currently not used within the Water Board. The meeting was also a starting point to get in touch with the asset manager which were in charge of the FED of these MR&R projects. Unfortunately, this never happened as they seemed to have no interest in an interview on this topic.

Interviewee TU2

Interviewee TU2 is an Associate Proferssor Public Commissioning at the Delft University of Technology. His field of expertise is mainly related to real estate instead of transportation infrastructure. However, the interviewee mentioned that within the real estate business, a lot of MR&R projects are going on as well. Within the real estate business, housing corporations for example often work in a project-based matter. The MR&R interventions are often separated in three flows: (1) Maintenance to improve the performance, (2) Energy consumption of the complex and (3) entire renewals or replacement of parts of the building like the floors or the facade. Real estate corporations often make a multi-annual maintenance planning to determine which MR&R activities are going take place and when.

However, the interviewee mentioned that he sees opportunities to cluster multiple projects consisting of multiple buildings (assets). Currently, so-called 'treintjes' are becoming more popular to execute a bunch of separate projects sequentially. In the form of strategic partnerships, housing corporations and contractors cooperate in an building transcending matter. The interviewee mentioned that potential benefits of a portfolio or program based approach, in his opinion, would be the more efficient management of the process, integration of tenants in the activities, creation of a continuous workflow with suppliers. On the other side, the warns for the risk of making the process too complex as the scope is increased to much and that the dependency on one supplier may become too large.

Thereby, the interviewee mentioned that MR&R challenges for housing corporations is often more than a technical challenge, compared to the transportation infrastructure sector. Since housing corporations have to deal with their tenants, MR&R challenges also have an important social aspect. Thereby, the investments have to be made by the housing corporations, which have to retrieve their investments from the rental of their houses within the complex. Therefore, the interviewee mentioned that from a technical perspective, it may be beneficial to work in a program based manner. However, having these social complexities also demands strict alignment and management of the MR&R acitivities in a building.

C EXPERIMENT BACKGROUND INFORMATION

C.1 OVERVIEW OF TRANCHE 4

Tranche 4 exists of 40 projects which are spread all across the Netherlands. Appendix D provide an overview of all projects within Tranche 4.

C.2 POTENTIAL GROUNDS FOR CONFIGURATIONS

Based on the requirements, as stated in subsection A.1.1, the overview explains briefly how achievement of these requirements can possibly be achieved. Of all requirements which were developed for Tranche 4, the requirements which aim to improve internal procedures (as shown in figure 4.1 are excluded. Reason for this, is the complexity of relating these requirements to the configuration of individual assets. Achievement of these internal processes are related to more general trade-offs, which relate to the decisions in for example the segmentation, interfaces and agility dilemma. The requirements discussed below are more focused on the performance of (multiple) projects and how these could be achieved.

Performance:

1. Cost optimization: Configure project such which create opportunities for efficient procurement, economies of scale or use standardized products
2. Knowledge building: Create room to use gained knowledge in the development of later on projects
3. Stimulating, developing and implementing innovations: Providing physical and financial space to develop new technologies, processes and concepts
4. Sustainability and circularity: Reduce environmental impact and operate circular

Benefits related to the performance of a MR&R project or program are to be realized if configurations consist of multiple assets which have certain similarities. These similarities have to be related to the physical characteristics of an to be renewed or replaced asset. If for example a configuration exist of five movable steel bridges, procurement can executed be more efficient (1), economies of scale may apply (1), contractors and the client have the opportunity to learn working with the same technique (2), new innovations can be tested and recouped on a larger scale (3) and opportunities to merge R&D expenses for new sustainability and circularity solutions can be merged (4).

Surroundings:

5. Consistent spatial development: Corresponding design and visual aspects of the assets in the region
6. Limited Vehicle Loss Hours: Minimize the vehicle loss hours as a consequence of the MR&R works
7. External nuisance communication: Inform the surroundings of to-be executed MR&R works and related nuisance
8. Minimizing negative impact of MR&R activities: Minimize nuisance to the environment as a consequence of MR&R works on the long term

9. Cooperation with local stakeholders: Align MR&R work with other developments or construction plans in the area

Benefits to the requirements related to the surroundings are logically more likely to be achieved, if assets which lay in a certain demographic proximity are merged into a project or program. By merging nearby assets in a project, visual appearance of the assets with the area is easier to streamline (5), planning of activities in relation to alternative routes is more organized (6), nuisance communication towards the surrounding can be done in a standardized and clear manner (7), necessary nuisance to the surroundings can be combined in one contiguous period (8) and cooperation with local stakeholders is easier to develop (9).

Collaboration with the market:

10. Opportunities for local contractors: Presence of MR&R activities which are financially and physically possible for smaller enterprises (Dutch: MKB)

11. Availability of capable contractors: Presence of multiple contractors to be able to execute the MR&R works.

Benefits related to public-private collaboration are created by the configuration of a balance diversity of projects and programs. Logically, if the scope of the configured programs are relatively small, abilities for local and often smaller contractors to execute the work is possible (10). While some MR&R interventions may require certain expertise, consideration of the present availability of suitable contractors may prevent complexities when moving from the configuration to the procurement phase (11).

C.3 POTENTIAL CONFIGURATION OPTIONS

Given the characteristics of Tranche 4, the following configuration options are determined:

- **Individual bridge compartment:** Substructure, superstructure, foundation, mechanical installation or controlling mechanism
- **Full bridge:** All of the above aspects in one project
- **Cluster based on similar compartments:** Combination of assets which require MR&R interventions to a specific bridge component
- **Cluster based on bridge type:** Combination of similar bridge types like: fixed, movable etc.
- **Cluster based on location:** Combination of bridges within a certain geographical boundary
- **Cluster based on corridor location:** Combination of bridges across the same highway or waterway
    1. **Only bridges on a corridor:** Focus of MR&R works only on the bridges
    2. Bridges on corridor including MR&R works to the highway or waterway in between

Together with the mentioned configuration options, logically combinations of the potential cluster options are present, like:

- **Cluster based on similar components and bridge type**
- **Cluster based on similar components and location**
- **Cluster based on similar components and corridor location**
- **Cluster based on similar location and bridge type**
- **Cluster based on corridor and similar bridge type**

C.4 CONFIGURATION OF BRIDGE PROJECTS IN TRANCHE 4

Due to the decision to test the developed FED process separately, table C.1 provides an overview of the bridges, based on the present information regarding the asset conditions. The table is a summary of all the asset passports which were developed, based on the present information gathered with the intakes which took place for Tranche 4. Since some intakes were not complete or available, it was not possible to gather all of the relevant information of all assets.

Yet, based on the present information, examples of (plausible) configurations are presented in chapter 6.

No.	Bridge	Highway	Waterway	Necessary intervention	Chrome VI	Traffic rates	Movable	Material	Length	Province	City
1	Van Brienenoordbrug	A16	Nieuwe Maas	Fixed, Movable, Impositions, Expansion joints, Cables , Control, Mecahnical	Yes	230.000	Yes	Steel	300 + 50	Zuid-Holland	Rotterdam
2	Brug over ringvaart Badhoevedorp	A4	Ringvaart van de Haarlemmermeer	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Noord-Holland	Badhoevedorp
3	Ijsselbrug	A12	IJssel	Fixed	Yes	20.000	No	Steel	138	Gelderland	Deventer
4	Giessenbruggen	A20	Delfshavense Schie	Movable, mechanical and control	Likely	107.000	Yes	Steel	150+15	Zuid-Holland	Rotterdam
5	Haringvlietbrug	A29	Hollands Diep	Fixed, movable , mechanical	Yes	54.000	Yes	Steel	1000 + 42,5	Zuid-Holland	Numansdorp
6	Draaibruggen Stevin / Lorentz	A7	Ijsselmeer	Movable , mechanical	Likely	21.000	Yes	Steel	Unknown	Friesland	Afsluitdijk
7	Schellingwouderbrug	-	Buiten IJ	Unknown	Unknown	13.600	Unknown	Steel	105	Noord-Holland	Amsterdam
8	Buitenhuizerbrug	N202	Noordzeekanaal	Movable, mechanical	No	10.000	Yes	Steel	21	Noord-Holland	Velsen-Zuid
9	Brug over de Westerwoldsche Aa	A7	Westerwoldsche Aa	Movable, mechanical, controls	No	13.000	Yes	Steel	70 + 13	Groningen	Oudezijl
10	Brug over de Goereese sluis	N990	Zeehavenkanaal	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Zeeland	Goeree Overflakkee
11	Algerabrug	N210	Hollandse Ijssel	Unknown	Yes	50.000		Concrete + Wood	24+24	Zuid-Holland	Cappele a/d Ijssel
12	Papendrechtse brug	N3	Beneden Merwede	Movable , mechanical	Yes	66.000	Yes	Steel	203+ 33	Zuid-Holland	Papendrecht
13	Erpsebrug	-	Zuid Willemsvaart	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Brabant	Veghel
14	Kelperbrug	N280	Wessem Nederweert Kanaal	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Limburg	Kelpen-Oler
15	Koningsbrug	N31	Van Harnixmakanaal	Fixed, movable , mechanic	Likely	Low	Yes	Concrete + V	26 + 15	Friesland	Harlingen
16	Hooivaartbrug	N31	Haerrenfeanster Kanaal	Movable, control	Likely	Low	Yes	Concrete +S	10	Friesland	Haskerdijken
17	Brug 1 - Nederweert	N275	Nederweert Kanaal	Fixed	Unknown	Low	No	Concrete	10	Limburg	Nederweert

Figure C.1: Overview of the bridges in Tranche 4

D | ADDITIONAL CASE INFORMATION

D.1 CASE 1 – VERVANGING EN RENOVATIE OPGAVE (VENR) – RIJKSWATERSTAAT

Vervanging en Renovatie
objecten en projecten in kaart

Rijkswaterstaat
Ministerie van Infrastructuur en Waterstaat

Vervanging en Renovatie projecten die al in uitvoering zijn of al zijn afgerond staan in deze kleine kaart. →

Versie 12 maart 2020

E EXPERT REVIEW SESSION

Based on the developed theoretical background, the held interviews and the consecutive analysis, the decision-making framework (as presented in figure 5.11 was created. In order to validate the findings of the analysis and the created decision-making framework, an expert review session is organized. This expert review session was held as part of a knowledge sharing event, organized by the Municipality of Amsterdam and Rijkswaterstaat. To support the findings as presented in 6.2, this Appendix will elaborate on the validation protocol and the results of the expert review session.

E.1 EXPERT REVIEW PROTOCOL

E.1.1 Purpose of the expert review session

The validation in chapter 6 consist of two parts: an imitation experiment and an expert review session. Yet, the purpose of the imitation experiment is to test the functioning of the decision-making framework in an existing case. This is done, by mirroring the developed framework to an existing case. Next to this imitation experiment, the framework is tested by evaluating the framework. This evaluation is to be executed by a group of experts which are facing MR&R challenges in their daily operations. Since the framework was created on a combination of scientific and empirical insights of multiple cases, the merger of these insights in one framework may not correspond with reality. Therefore, based on the experience and expertise of several practitioners, the completeness, the functioning and the usability of the developed decision-making framework is reviewed.

E.1.2 Methodology

The expert review session consists of three objectives:

1. **Completeness:** Validate the content of the decision-making framework. Are the trade-offs in the developed decision-making framework the actual trade-offs which public organizations experience while trying to design their FED process?

2. **Functioning:** Validate the potential effects of to-be made trade-offs. In chapter 5, every trade-off is supported with an explanation of the related considerations. These considerations consist of consequences on the FED process while making a decision on a present trade-off. Are the identified effects of certain decision corresponding with reality or are aspects overlooked?

3. **Usability:** Validate whether the decision-making framework is applicable for the persons involved. The identified dilemmas were characterized according to a certain institutional level where the dilemma occurs. However, the institutional level where the dilemma is present does not naturally corresponds with the division of decision-making authority within an organization. Therefore, the usability of the developed decision-making framework is tested in order to gain insights in the authority to make the identified trade-offs within organizations.

To fulfill the objectives during the expert review session, the objectives are separately tested. Insights of the session will function as input for the developed decision-making framework and its considerations. An overview of the validation procedure is visualized in figure E.1

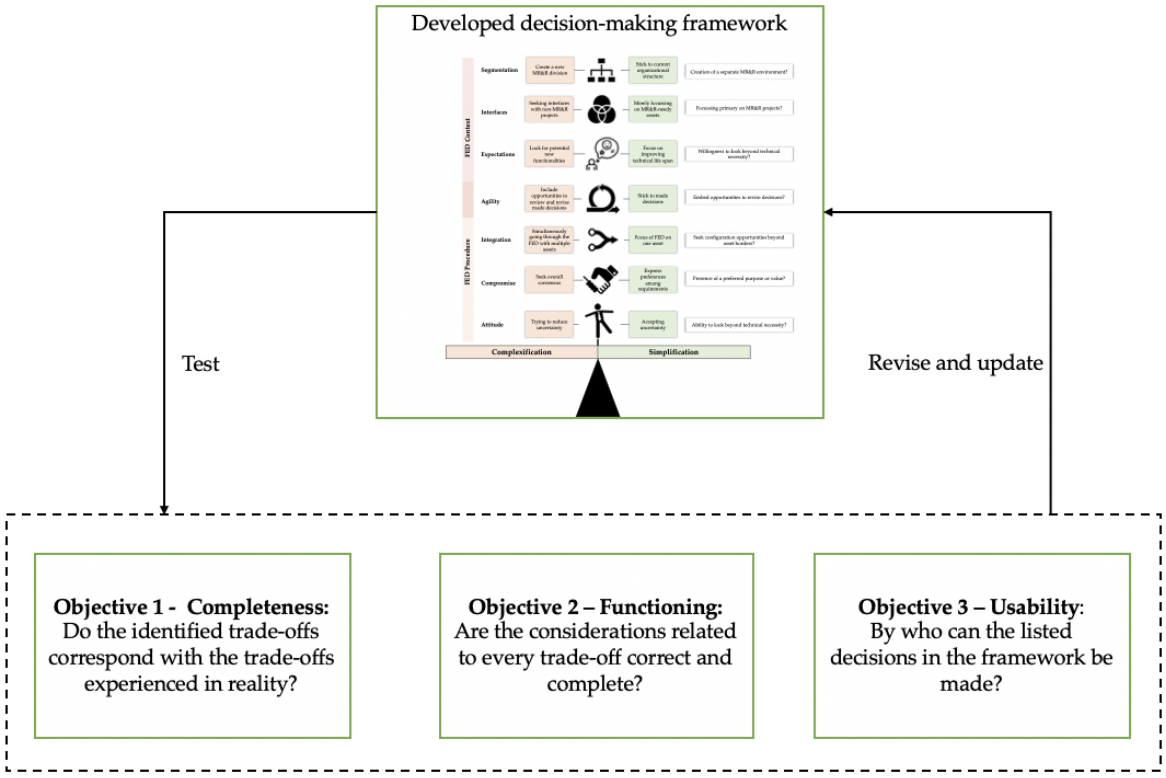


Figure E.1: Overview of the validation procedure

To compose answers on the stated objectives in the relatively short time-frame of the expert review session, the following procedure was followed: First, a presentation was given to explain the research to the participants and to show the decision-making framework. After the decision-making framework and the underlying considerations were explained, the mentimeter application was used to ask some questions regarding the stated objectives. After the questions were asked while using the Mentimeter, a discussion will be held with the participants regarding the stated questions. While making use of the mentimeter application, participants can write down their anonymous answers on the questions, which creates the opportunity to create significant amounts of answers on a question in a relatively short time frame. The afterwards discussion and the remaining knowledge sharing event can be used to dig deeper into the validation of the decision-making framework.

E.2 RESULTS OF THE EXPERT REVIEW SESSION

In addition to the findings of the expert review session as presented in section 6.2, the following subsections will provide an overview of the participants and the mentimeter answers.

E.2.1 Participants

The participants of the expert review sessions were of both Rijkswaterstaat and the Municipality of Amsterdam. From Rijkswaterstaat, the regional team which is in charge of the VenR challenge in West Netherlands North and a team member of the nationally operating VenR team were present. Of the Municipality of Amsterdam, the entire Program Board (except the Program Director) were present. In table E.1, an overview of the participants is provided.

No	**Organization**	**Division**	**Role**
1	Rijkswaterstaat	West Netherlands North	Project controller
2	Rijkswaterstaat	West Netherlands North	Surroundings Manager
3	Rijkswaterstaat	West Netherlands North	Integrated Project Manager
4	Rijkswaterstaat	West Netherlands North	Technical Manager
5	Rijkswaterstaat	West Netherlands North	Contract Manager
6	Rijkswaterstaat	Large Projects and Maintenance	Member of VenR team
7	Municipality of Amsterdam	Program Bridges and Quay Walls	Director Safety, Knowledge and Advice
8	Municipality of Amsterdam	Program Bridges and Quay Walls	Director Guidance and Control
9	Municipality of Amsterdam	Program Bridges and Quay Walls	Director Surroundings
10	Municipality of Amsterdam	Program Bridges and Quay Walls	Director Programming and Accelleration
11	Municipality of Amsterdam	Program Bridges and Quay Walls	Official client (NL: Ambtelijk opdrachtgever)
12	Municipality of Amsterdam	-	Alliance Manager and organizer of event

Table E.1: Overview of the participants of the expert review session

E.2.2 Outcomes of the validation questions

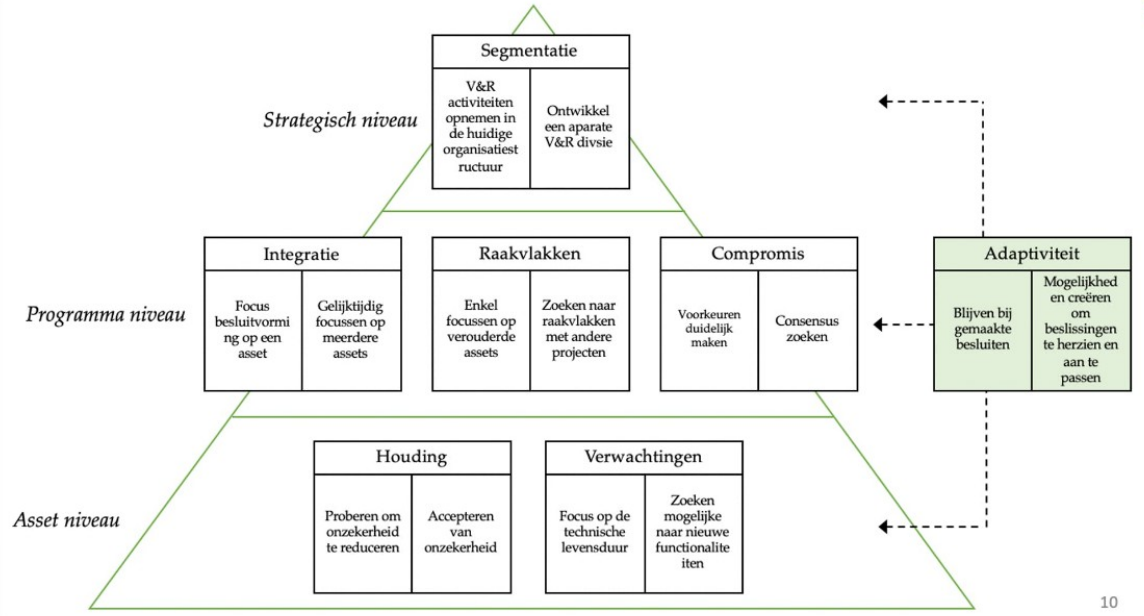
As an addition to the explanation of the findings in section 6.2, the following slides function as the representation of the raw results. Since the entire event was in Dutch, the documentation is in Dutch as well. The first document shows an representation of the answers on the Mentimeter questions. The second document is a summary of the knowledge sharing event, including the discussed dilemmas.

Vraag 1: Verantwoordelijkheden en mandaat

Wie is / zijn er binnen jouw organisatie in staat om deze beslissingen te nemen?

4

?



?

Wie is er binnen jouw organisatie in staat om deze beslissingen te nemen?

Bestuur	Bestuur RWS	Bestuur
Bestuur	Strategisch niveau: B&W	Programma
Programma	Strategische: bestuur	Programmateam

Wie is er binnen jouw organisatie in staat om deze beslissingen te nemen?

Mentimeter

Bestuur

Bestuur van Rijkswaterstaat Programmateam

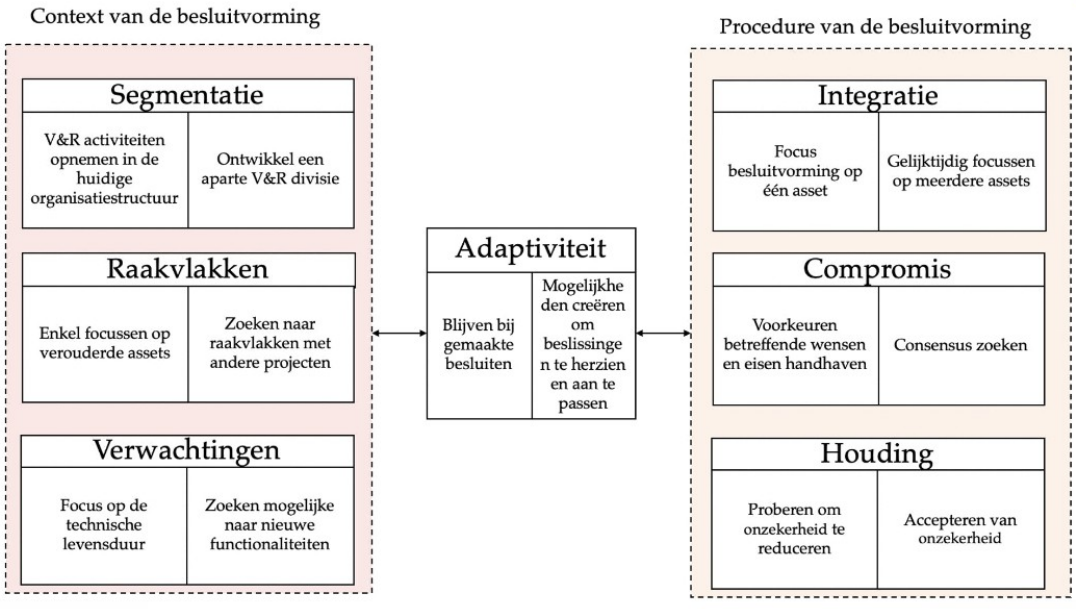
11

Mentimeter

Vraag 2: Toevoegingen aan het model

Zijn er binnen jouw organisatie nog andere afwegingen die meespelen?

?



Zijn er binnen jouw organisatie nog andere afwegingen die meespelen?

Mentimeter

- Effect op bereikbaarheid
- Relatie met huidig asset management
- Mensen mensen mensen
- Hoe verhoud je je tot de omgeving?
- Innovatie mobiliteit
- Omgeving en Politiek bestuurlijke contextOmgeving en Politiek bestuurlijke context
- Markt markt markt
- Meekoppelkansen vanuit de omgeving
- Politieke invloed

10

Zijn er binnen jouw organisatie nog andere afwegingen die meespelen?

Mentimeter

- Duurzaamheid

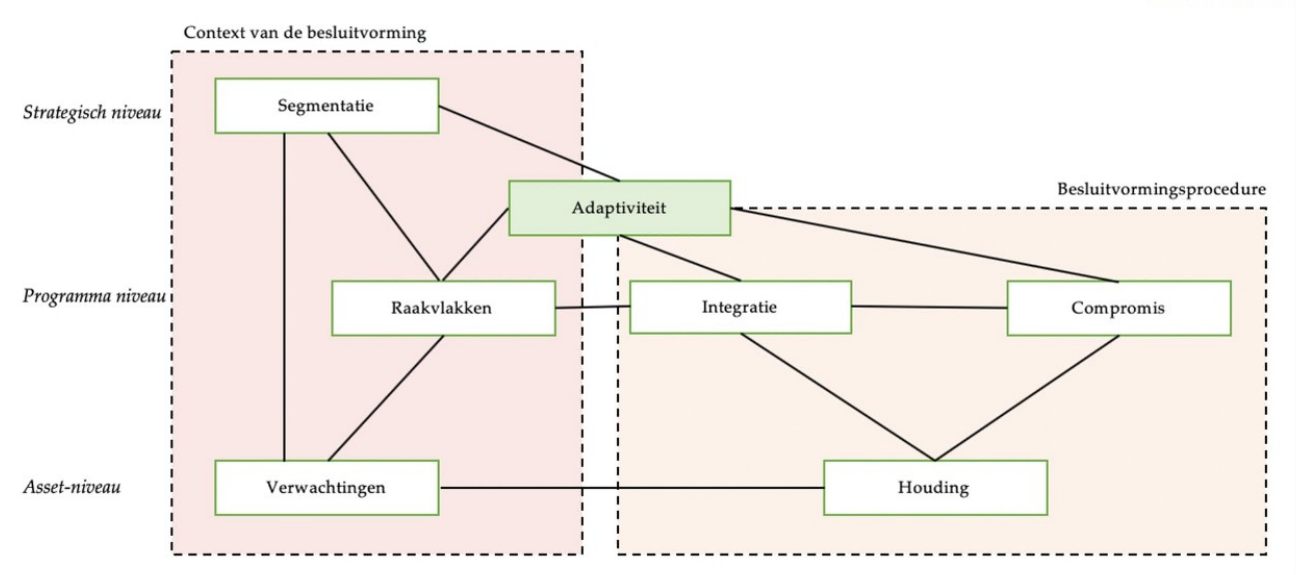
10

Mentimeter

Vraag 3: Risico's van het vergroten van de oplossingsruimte

Wat zijn volgens jou mogelijke risico's van het vergroten van de oplossingsruimte?

1



Wat zijn volgens jou mogelijke risico's van het vergroten van de oplossingsruimte?

- Dan kom je niet op gang
- Trek m breed, gebeurt er geen...
- Beheersbaarheid
- Snelheid omlaag, geen focus
- Risico's koppelkansen: meer complexiteit, tijd nodig voor afstemming en ontwikkeling, veel wijzigingen en verstoringen
- Samenwerkingsverbanden
- Oplossing sluit niet goed aan op de lokale omgeving
- Minder lokaal maatwerk (omgeving)?
- Fataal integraal (regie)

11

Wat zijn volgens jou mogelijke risico's van het vergroten van de oplossingsruimte?

- Groot versus beheersbaar, grenswaarde?
- Governance

11

Bijeenkomst
Programma V&R Rijkswaterstaat WNN
Programma Bruggen en Kades Amsterdam

10 maart 2020, SHIP IJmuiden

Dit document vormt niet een verslag van de bijeenkomst, maar geeft de input en reflectie op elkaars aanpak en dilemma's, zoals we hebben opgehaald tijdens de bijeenkomst.

AANPAK RIJKSWATERSTAAT WNN

Reflectie door Amsterdam

Wat verwondert je in de aanpak?

1. Personen met een dubbelrol in programma en project
2. Bestaande situatie is 'ander' onderzoeksvraag?
3. Zeer lang voorbereidingstraect met overdrachten?
4. Scopebepaling voor programmering planfase?
5. Waarom zijn jullie een IPM team?
6. Levernsduur verlengen: verduurzamen als project, of duurzaam vervangen? *Opmerking RWS: drie focusunten: (1) verjongen, (2) vernieuwen, (3) verduurzamen.*
7. Per object functie opnieuw beoordelen? Doe je dat puur object, of in relatie tot de omgeving? *Opmerking RWS: object is de aanleiding. Dan bekijken we vervolgens het object in relatie tot de omgeving. Zijn daar veranderingen (gaande), die maken dat een brug bijvoorbeeld niet meer beweegbaar hoeft te zijn. Uitdaging is om het vraagstuk niet te groot/breed te maken. Je loopt kans in een brede en langdurige afweging te belanden, over bijvoorbeeld verkeersnetwerken en (vaar)weg klasse.*

Welke tips heb je?

-

Over welk onderwerp zou je eens door willen praten?

OBJECT irt OMGEVING

1. Afweging object in relatie tot de omgeving.
2. Van object naar gebiedsaanpak. Corridor aanpak.

VAN INCIDENTMANAGAMENT NAAR PLANMATIGE AANPAK

3. Stap zetten van 'het overkomt ons wat we moeten doen' naar 'we kiezen en programmeren op navolgbare principes'.
4. Expliciteren overzicht over de opgave met als doel (o.a.) om te komen tot standaardisatie / seriematige aanpak

SAMENHANG PROGRAMMA / PROJECT

5. Programma of optelling van een aantal projecten?
6. Zichtbaarheid overall programma versus projectteams die meer assets te doen krijgen.

7. Hoe stel je een tranche (combi van projecten) samen? Langs welke lijn? Bijvoorbeeld, prio staat / gebied / bereikbaarheid / …

   BUDGET BEPALING
8. Moet je wel een budget bepalen en in welke fase van de slang?

AANPAK AMSTERDAM PBK

Reflectie door Rijkswaterstaat

Wat verwondert je in de aanpak?

1. Grootte van de opgave (850 bruggen en 200 km kade) ten opzichte van oppervlakte (in vergelijking met RWS).
2. Veranderopgave van werkwijze / besluitvorming heeft andere 'skills' nodig dan je gewend bent. Hoe doe je dat? Zet je daar(om) de Triple Helix in?
3. Zelf de technische staat bepalen waarom niet gelijk aan de slag gaan? Je hebt namelijk al een indicatie van de staat van de bruggen / kades?
4. Leren en ontwikkelen. Een mooie plek in de opzet van jullie programma (opschaalbaar). Experimenteren en pilots (living labs) verwerken in programma (state of the art).
5. Wat is het belangrijkste / wat heeft prioriteit? Levensduur verlengen vs (lange termijn) Hinder vs Geld vs Veiligheid.
6. Jullie zeggen dat veiligheid voorop staat maar er zijn al wel incidenten geweest (verzakkingen). Staat veiligheid dan wel echt voorop? Bij RWS is een duidelijk uitgangspunt: wat er ook gebeurt, er mag geen incident plaatsvinden.
7. Wordt er volledig ingezet op verandering en innovatie? Dat lijkt uit de presentatie zo.

Welke tips heb je?

8. Dempen van havens en grachten 😊

Over welk onderwerp zou je eens door willen praten?

TEMPO / OPSCHALING

1. Opschaling / tempo / hoe haal je de piek eraf
2. Fabrieksmatige aanpak
3. Corridoraanpak (zoals bij Oranje Loper)
4. Normaal – versnellen.
5. Piek wegwerken

VAN INCIDENTMANAGAMENT NAAR PLANMATIGE AANPAK

6. Planmatig werken vs incident management
7. Programma vs productie – ontwikkelen productie proces / aanpak
8. Van ideen naar: prioriteren – plannen - uitvoeren

ACCEPTEREN versus TEGEN Gaan

9. Toestand – inspectie 'te kort' – risico beheersing

OMGEVINGSMANAGEMENT

10. Omgevingsmanagement : minder hinder. Verbinden.

MARKT BETREKKEN

11. Hoe zetten jullie de markt in bij het realiseren van de opgave
12. Wie ontwikkelt de (innovatieve) bouwmethoden, zoals in de nabijheid van funderingen oude woningen? En wie is hier verantwoordelijk voor? Hoe leg je deze bouwwijze op ?

DILEMMA's

We bespreken enkele dilemma's.

Enkele reflecties en suggesties:

- Meekrijgen van medewerkers etcetera conflicteert met termen als:
    - 'Alles moet anders'
    - 'sterk inzetten op Innovatie'.
- Niet iedere stakeholder (intern en extern) staat open voor verandering. Die raak je kwijt met bovengenoemde termen.
- Aanpak lijkt erg gericht op het 'hoe'. Let op dat je ook genoeg aandacht besteedt aan het 'waarom'. Neem je omgeving mee in het verhaal Als programma kan het waarom zo vanzelfsprekend zijn, dat je vergeet anderen bij herhaling mee te nemen in waarom al deze maatregelen nodig zijn.
- Zorg dat je eigen overtuigingen niet te leidend zijn.
- Andere aanpak zou kunnen zijn, om betrokkenen mede verantwoordelijk te maken voor de opgave / het resultaat. Bijvoorbeeld, veel weerstand tegen bomenkap. Maak de tegenstanders onderdeel van je programma, door hen zelf met oplossingen te laten komen die passen binnen de gestelde kaders.
- Idee: Wisselkade voor woonboten
-
- In de driehoek 'verbinding', 'tempo maken' en 'resultaat' kun je niet aan alle drie even veel gewicht geven en standvastig zijn. Bepaal, welke leidraad is flexibel en welke wil je strak aan vasthouden.
-

- Verschillende soorten mensen: zij die open staan voor verandering en zij die willen behouden wat is. Realiseer je dat en bedenk in welke groep je je energie in wilt steken. Moet je iedereen overtuigen en in de meewerk stand krijgen, of wil je ook gewoon opleggen? , zoals met de beoogde verordening (dilemma 2).

We bespreken de overweging om partijen mee te krijgen dan wel om de scherpte op te zoeken. Er wordt gerefereerd aan de Cie Cloo*, die al aangaf dat veranderen nodig is en dat dit zeker zal botsen met de bestaande cultuur in de gem Amsterdam.

- Zorg dat je bestuurlijk hiervoor de handen op elkaar hebt (check)
- Daarmee heb je mandaat om verandering te brengen, en hoef je dus niet iedereen mee te krijgen. Je kunt doorzettingskracht gebruiken. Zoek de weerstand dus (juist) op en zorg daarbij dat je steeds de bestuurlijke macht achter je hebt staan.

**) De heer Cloo doet vijf aanbevelingen. In de eerste plaats moet de belasting van de kades en bruggen in de vorm van zwaar verkeer drastisch worden geweerd. Daarnaast moet de programmatische aanpak van bruggen en kades worden versterkt, de financiering van het programma flexibeler worden, en structureel beschikbaar zijn. Ook moet er geïnvesteerd worden in de organisatie. De vijfde en laatste aanbeveling luidt dat de gemeente moet kiezen voor schaalvergroting op innovatie en samenwerking met de markt en kennisinstituten.*

VERVOLG

Willen we een vervolg geven aan deze bijeenkomst? Ja, het voelt nuttig en zinvol. We zien voldoende aanknopingspunten voor volgende bijeenkomsten. Dat hoeft niet per se met dezelfde groep. Afhankelijk van het onderwerp en de insteek kan een bijeenkomst plaatsvinden met een deel van

deze groep en mogelijk met andere relevante partners. Als voorbeeld wordt Prorail genoemd en de Amsterdamse wegtunnels.

Voorwaarde voor volgende bijeenkomsten:
Onderwerp moet interessant zijn voor alle betrokkenen. Daarom, een (inhoudelijk) onderwerp vooraf goed voorbereiden vanuit de insteek dat er voor alle betrokken partners voordeel uit te halen valt (wederkerigheid).

Vorm: de dilemma's die we 10 maart bespraken, behandelden we in de vorm van spiegelsessie / intervisie. Dat bleek een handige vorm, maar andere werkvormen zijn ook mogelijk. Al naar gelang doel en beoogd resultaat bijeenkomst.

In deze bijeenkomsten zijn onderwerpen genoemd waarover we verder zouden willen doorpraten. Daar kunnen we uit putten voor (een) volgende bijeenkomst(en). Vergt nadere uitwerking.

F GEBRUIKERSHANDLEIDING

In deze bijlage wordt het gebruik van het ontwikkelde framework verder toegelicht, om er voor te zorgen dat het framework toegepast kan worden door publieke opdrachtgevers met een vervanging- en renovatie opgave.

In essentie is het framework bedoeld om de FED fase, ookwel omschreven als de verkenningsfase, van vervanging- en renovatie opgaven te structureren. De gedachte hierachter komt voort uit wetenschappelijke theorieën, die stellen dat tijdens de FED fase de mogelijkheid om waarde te creëeren in een project het grootst is terwijl de impact van mogelijke beslissingen en veranderingen op de voortgang van een project minimaal zijn [Burke, 1999; Edkins et al., 2013]. Om de mogelijkheden van een vervanging- en renovatie opgave zo uitgebreid mogelijk te benutten, heeft het framework de afwegingen in kaart gebracht die dit FED proces vormgeven. Door de afwegingen uit het framework te maken kan een publieke opdrachtgever het FED proces dusdanig afstemmen op de aanwezige wensen, uitdagingen en beschikbare middelen.

Het framework, zoals gepresenteerd in figuur F.1 zal per dilemma toegelicht worden om zo een verbeterd inzicht in de methodiek te krijgen. Deze toelichtingen zijn gebaseerd op de bevindingen in hoofdstuk 5.

1. **Segmentatie:** Om de MR&R opgave aan te pakken, kan er voor gekozen worden om (een deel van) de opgave onder te brengen in een aparte divisie binnen de organisatie of afdeling. Door alle assets die toe zijn aan een vervanging of renovatie in een aparte omgeving onder te brengen, neemt de kans dat raakvlakken gevonden worden toe. Deze mogelijke raakvlakken kunnen er voor zorgen dat er voordelen behaald kunnen worden door meerdere assets gezamenlijk te vervangen en / of renoveren, zoals bijvoorbeeld in het KARGO programma (zie A.2).

2. **Raakvlakken:** Naast veranging- en renovatie projecten heeft een organisatie te maken met aanleg- en onderhoudsprojecten. Nu kan het voorkomen dat de asset die vervangen of gerenoveerd moet worden bepaale raakvlakken heeft met andere soorten projecten, door bijvoorbeeld een naburige ligging of omdat het onderdeel is van dezelfde (water)weg. De opdrachtgever heeft hier de mogelijkheid om deze projecten onafhankelijk van elkaar te realiseren of om er voor te kiezen om deze projecten gezamenlijk te ontwikkelingen.

3. **Verwachtingen:** Vaak zal de eindige levensduur van een asset de aanleiding zijn om actie te ondernemen. Echter, the opdrachtgever heeft hier de mogelijkheid om de scope van het project te houden bij het verhogen van de resterende technische levensduur. Aan de andere kant kan de opdrachtgever de vervanging- of renovatiebehoefte van de asset zien als een kans om de huidige functionaliteit van de asset te toetsen. Mogelijk zijn er nieuwe wensen vanuit de omgeving of met betrekking tot het gebruik welke samengevoegd kunnen worden met de bestaande opgave om de resterende technische levensduur aan te pakken.

4. **Adaptiviteit:** Tijdens de FED bestaat het process uit meerdere stappen welke allemaal tijd kosten en afhankelijk zijn van eeder gemaakte besluiten. Echter, er kunnen zich situaties voordoen waarin een gemaakt besluit om moment A niet meer het beste besluit blijkt te zijn op moment B. Doordat er over de loop van tijd nieuwe informatie beschikbaar is gekomen, doordat er wensen en eisen veranderd zijn of door andere activiteiten, kan het voorkomen dat het herzien van een beslissing wenselijk is. Hiervoor moet echter wel ruimte in het FED process vrijgemaakt worden. Door in het FED process momenten in te bakenen om de huidige ontwikkelingen te toetsen aan de beschikbare informatie, middelen en wensen van dat moment kan er voor gezorgd worden dat een opgave en de daarbij behorende projecten tot een betere uitkomst leiden dan op basis van eerder genomen besluiten.

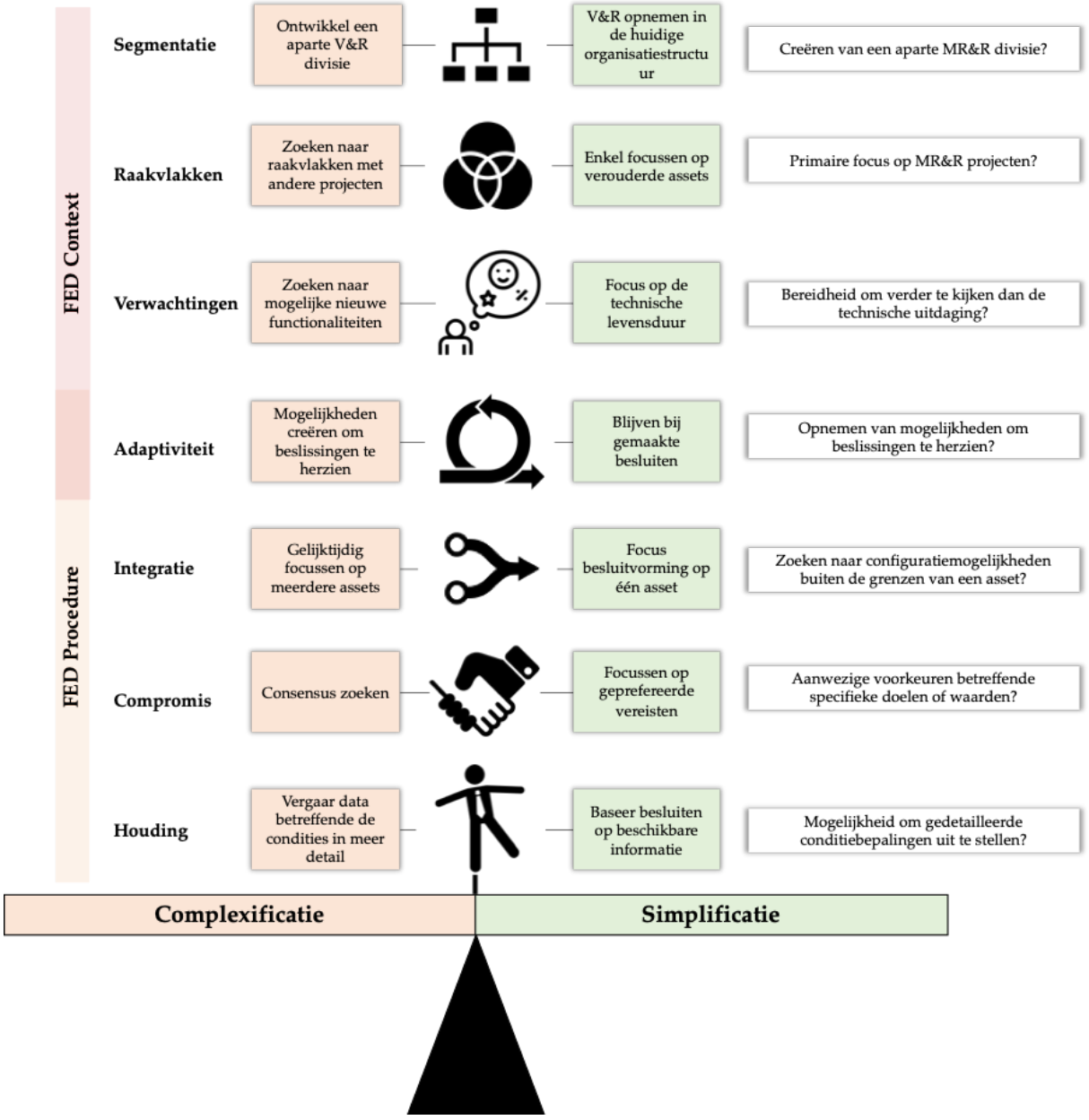


Figure F.1: Overzicht van het besluitvormingsframework

5. **Integratie:** De verkenning en voorbereiding van een vervanging- en renovatie opgave kan voor elke asset individueel gedaan worden. Het vaststellen van de huidige staat, het afwegen van mogelijke vervanging- en renovatie alternatieven en het maken van een voorkeursbeslissing betreffende de uitvoeringsvorm van een project of programma kan echter ook gedaan worden in presentie van meerdere assets op hetzelfde moment. Door het FED proces gelijktijdig te doorlopen voor meerdere assets, kunnen mogelijke kansen gezien en benut worden die individueel niet mogelijk blijken te zijn.

6. **Compromis:** Gezien een huidige situatie kan het zo zijn dat een publieke opdrachtgever een bepaalde vereiste heeft welke zij graag gerealiseerd wilt zien. Dit kan variën van het waarborgen de veiligheid tot het realizeren van duurzaamheidsambities en het vergaren van kennis en ervaring op bepaalde gebieden. Indien deze voorkeuren aanwezig zijn, kan een opdrachtgever er voor kiezen om deze doelstellingen een zogenaamde voorkeursbehandeling te geven. Door de voorkeur uit te spreken voor een bepaalde doelstelling of vereiste, kan de FED en de daarbij behorende configuratie van projecten en programma's zich hier op richten. Indien dit niet aan de orde is, of er geen dusdanige preferentie aanwezig is zal de opdrachtgever er voor kunen

kiezen om een compromis te sluiten met de belanghebbenden en hun bijbehorende vereisten en doelstellingen.

7. **Houding:** Afhankelijk van de staat waarin een asset verkeerd, kan de opdrachtgever er voor kiezen om gedetailleerde onderzoeken betreffende de staat van een asset door te schuiven naar projectfases na de FED. Deze conditiebepalingen blijken een significante impact te hebben op de FED procedure, aangezien ze vaak complex en daarmee tijdrovend en kostbaar zijn. Indien er vastgesteld of aangenomen kan worden dat de staat van de asset toereikend genoeg is om niet onmiddelijk actie te ondernemen, kan de opdrachtgever er voor kiezen om deze activiteiten geen onderdeel te maken van de FED procedure. Door niet enkel naar de technische staat van assets te kijken, maar ook naar andere karakteristieken zoals: locatie, materiaal en besturingssystemen, kunnen configuraties ook op deze karakteristieken gemaakt worden. Om dit te kunnen doen en de gedetailleerde conditiebepalingen dus uit te stellen, moet een publieke opdrachtgever wel de mogelijkheid hebben om met aanzienlijke zekerheid te zeggen dat onmiddelijke interventie niet aan de orde is.

Zoals te zien is in figuur F.1, is er binnen elk dilemma een afweging te maken welke enerzijds voor simplificatie en anderzijds voor complexificatie zorgt. De beslissing ten faveure van simplificatie zorgt er voor dat het FED proces eenvoudig en overzichtelijk blijft. Aan de andere kant, is de mogelijkheid dat aanwezige kansen met betrekking tot de vervanging en renovatie van een asset benut worden relatief klein, indien er voor simplificatie gekozen wordt. Vervaning- en renovatie opgaven worden namelijk vaak gekenmerkt door een verscheidenheid aan assets, raakvlakken, wensen en condities. Door tijdens de vroege FED fase niet verder te kijken dan de minimale scope van het vervangen of renoveren van een individuele asset, zullen (schaal)voordelen ook niet of lastig gerealiseerd worden.

De andere keuze die gemaakt kan worden stuurt aan op een complexificatie van het FED proces. Meerdere assets worden gelijktijdig behandeld, meerdere functionaliteiten worden in acht genomen en een breed scala aan wensen wordt geprobeerd gerealiseerd te worden waardoor meer raakvlakken en daarbij behorende overwegingen in acht genomen zullen moeten worden. De kans dat hiermee aanwezige kansen van een vervanging- en renovatie opgave worden benut neemt toe. Echter, de omvang van de besluitvorming tijdens de FED kan ook te groot worden, waardoor het geheel niet meer beheersbaar is voor de managers. Hierdoor kan vastgesteld worden dat een volledige complexificatie van het process op alle zeven punten er voor zal zorgen dat het proces ontspoord en niet meer onder controle is.

Door gebruik te maken van het framework, kunnen er weloverwogen keuzes gemaakt worden betreffende de indeling van het FED process. Ga na welke wensen, eisen, en middelen beschikbaar zijn binnen uw organisatie en hoe mogelijke keuzes in het ontwikkelde framework hier op kunnen aansluiten. Uiteindelijk gaat het om het vinden van een balans tussen simplificatie en complexificatie, aangezien volledige focus op een van deze twee aspecten er voor zal zorgen dat aanwezige kansen worden gemist of dat het FED proces onbeheersbaar wordt, respectievelijk.

COLOPHON

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