Towards Smarter Public Procurement for Infrastructure Renewal

Using DBFM principles for Replacement and Renovation Projects in the Netherlands

MSc Construction Management and Engineering

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TU Delft

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by

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In partial fulfilment of the requirements for the degree of Master of Science In Construction, Management and Engineering at the Delft University of Technology.

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Preface

With gratitude, I present my Master's thesis as the final milestone of the MSc programme in Construction Management and Engineering at Delft University of Technology. During this research, I explored how DBFM design principles can support better procurement and collaboration for replacement and renovation projects in Dutch infrastructure. What motivated me throughout is the human side of our sector: technology and innovation create opportunities, but effective collaboration and trust determine the outcomes in practice.

I am grateful to my graduation committee, Prof. dr. ir. Marleen Hermans, ir. Leon Hombergen, and ir. Hans Ramler, for their guidance, critical questions, and steady support. A special word of thanks to Ed Onstee and to HOCHTIEF for welcoming me during the final part of my studies and for introducing me to many of the experts I interviewed. I also want to thank the many people at Rijkswaterstaat, provinces, municipalities, engineering firms, and contractors who shared their time and experience during interviews. To my family and friends: thank you for your encouragement, patience, and much needed distractions along the way.

I hope you enjoy reading my thesis!

Bram van Oord
Delft, October 2025

Summary

The Netherlands faces a prolonged period of infrastructure renewal as bridges, tunnels, locks and related assets built in the post-war construction boom reach the end of their service lives. Traditional procurement often struggles with complexity, efficiency and market capacity limits. This thesis asks how the principles behind Design Build Finance Maintain (DBFM) contracts can be used to improve the procurement and delivery of Replacement and Renovation (R&R) projects, not by prescribing DBFM as a single form, but by treating it as a modular set of design principles that can be tailored to project context.

The research objective is to translate DBFM principles into practical guidance for Dutch R&R contracting. The main question is: How can DBFM principles be used to improve contract design for replacement and renovation projects in Dutch infrastructure? To answer this, the study follows a Double Diamond approach. A literature review establishes the R&R challenge and extracts strengths and limitations of DBFM for renewal settings. In the next phase, semi structured interviews with public clients and contractors explore how individual DBFM elements perform in practice for R&R tasks, followed by expert validation to refine the framework and contract ideas. Interviews are transcribed and coded to compare perspectives across stakeholder groups.

The framework is based on six DBFM elements. (1) Private finance introduces external financial discipline and sharper risk management, but raises capital costs and can limit contractual flexibility in R&R settings. (2) Integrated delivery with a life cycle perspective (design build maintenance) encourages optimisation of total cost of ownership and smarter design choices. (3) Risk allocation follows the principle that risks are assigned to the party best able to manage them; this can improve efficiency and performance, but pushing too much risk to the private side reduces public steering and may dampen market interest. (4) Performance based payments and targeted incentives link remuneration to outputs such as availability and quality, which can stimulate quality, timeliness and innovation when well designed. (5) Long term collaboration and team continuity strengthen trust, knowledge transfer and continuous improvement, although transaction costs and dependency risks rise without proper safeguards. (6) Governance and collaboration: an SPC structure with roles such as EPC and MTC can pass through risks and formalise decision making, but it also demands strong public governance and technical capacity.

Two important themes strengthen the framework. First, a programmatic approach enables learning, resource smoothing and joint problem solving but requires strong client side governance and attention to competition. Second, industrialised and standardised construction can reduce design effort, enable economies of scale and support circularity, but faces barriers such as upfront investment, cultural resistance and limits to standardisation in bespoke renewal contexts. These themes are integrated into the advice on bundling, deal flow, and collaboration across public clients.

The core output is a decision making framework that links context to advice and then to contract design. Five context dimensions are defined and operationalised with observable indicators: uncertainty, complexity, repeatability, the importance of operations and maintenance, and scarce market capacity. For each advice, the framework records whether that advice becomes more valuable in a given context, may be counterproductive, or remains generally applicable. To use the framework decision makers profile a project based on these five context dimensions, prioritise the most relevant advice, and then translate them into coherent contract choices.

The final advice set emphasises avoiding private finance for most R&R contexts, giving priority to life cycle optimisation through integrated delivery, using phased contracts to reduce unknowns, balancing fixed, unit and reimbursable prices to protect flexibility without losing price discipline, using targeted incentives, investing in client side technical expertise, promoting long term collaboration, creating realistic deal flow, and stimulating standardisation and industrialisation across public clients.

To move from framework to practice, three context archetypes are profiled and mapped to three illustrative contract proposals that recombine DBFM principles with the four procurement components: delivery system, reward system, selection procedure, and collaboration model. Proposal 1 is a two phase integrated DBM with a system life maintenance horizon for high uncertainty and high complexity settings where learning across a small bundle and life cycle focus matter. Proposal 2 is a framework agreement with standardised solutions for highly repeatable assets, combining fixed prices for standard objects with unit rates for flexibility and using performance based ranking to determine deal flow. Proposal 3 is a budget driven open book portfolio model for capacity constrained environments with persistent uncertainty, using target cost with gain pain sharing, to economically optimise interventions. These are not templates but starting points, and hybrid forms are possible between the profiles.

The study contributes a systematic, context aware route from project characteristics to contract design for R&R. It reframes DBFM as a source of design principles that can be reused in non DBFM forms and shows how to operationalise them with clear choices on delivery, pricing, incentives and collaboration. Practically, the framework helps public clients profile their programme and select a fit for purpose combination of contract mechanisms that can help R&R projects.

The research is qualitative and tailored to the Dutch context and further testing is needed to rank or quantify the impact of individual advice. Future research should further investigate how and which incentives can help align contractor and client goals. Furthermore, more research should examine the most effective bundle size using a programmatic approach and which volumes and degree of standardisation are needed for industrialised construction.

Samenvatting

Nederland staat voor een langdurige periode van infrastructuurvernieuwing doordat bruggen, tunnels, sluizen en andere assets uit de naoorlogse bouwpiek het einde van hun levensduur naderen. Traditionele inkoop worstelt vaak met complexiteit, efficiëntie en beperkte marktcapaciteit. Deze scriptie onderzoekt hoe de principes achter Design Build Finance Maintain (DBFM) kunnen worden ingezet om de inkoop en uitvoering van vervanging en renovatieprojecten (V&R) te verbeteren, niet door DBFM als één uniforme vorm voor te schrijven, maar door het te benaderen als een modulaire set ontwerpprincipes die op de projectcontext kan worden afgestemd.

Het onderzoeksdoel is om DBFM-principes te vertalen naar praktische handvatten voor Nederlandse V&R contractontwerp. De hoofdvraag luidt: Hoe kunnen DBFM-principes worden gebruikt om het contractontwerp voor vervanging- en renovatieprojecten in de Nederlandse infrastructuur te verbeteren? Om deze vraag te beantwoorden volgt de studie een Double Diamond aanpak. Een literatuurstudie schetst de V&R-opgave en destilleert sterktes en beperkingen van DBFM in de vernieuwingscontext. In de volgende fase verkennen semigestructureerde interviews met publieke opdrachtgevers en aannemers hoe afzonderlijke DBFM-elementen in de praktijk presteren voor V&R-taken, gevolgd door expertvalidatie om het raamwerk en de contractideeën te valideren. Interviews zijn getranscribeerd en gecodeerd om perspectieven tussen stakeholdergroepen te vergelijken.

Het raamwerk is gebaseerd op zes DBFM-elementen. (1) Private financiering brengt externe financiële discipline en scherper risicomanagement, maar verhoogt kapitaalkosten en kan de contractuele flexibiliteit in V&R-contexten beperken. (2) Geïntegreerde levering met een levensduur perspectief (design build maintenance) stimuleert optimalisatie van de total cost of ownership en slimmere ontwerpkeuzes. (3) Risicoverdeling volgt het principe dat risico's worden belegd bij de partij die ze het best kan beheersen; dit kan efficiëntie en prestaties verbeteren, maar te veel risico bij de private kant neerleggen vermindert publieke sturing en kan de marktinteresse dempen. (4) Prestatiegerichte betalingen en gerichte prikkels koppelen de vergoeding aan output zoals beschikbaarheid en kwaliteit, wat bij goede vormgeving kwaliteit, tijdigheid en innovatie kan stimuleren. (5) Langdurige samenwerking en teamcontinuïteit versterken vertrouwen, kennisoverdracht en continue verbetering, al nemen zonder passende waarborgen de transactiekosten en afhankelijkheidsrisico's toe. (6) Governance en samenwerking: een SPC-structuur met rollen zoals EPC en MTC kan risico's doorleggen en besluitvorming formaliseren, maar vereist een sterke publieke governance en technische capaciteit.

Twee belangrijke thema's versterken het raamwerk. Ten eerste maakt een programmatische aanpak leren, capaciteitsverdeling en gezamenlijk probleemoplossen mogelijk, maar het vraagt om stevige governance aan opdrachtgeverszijde en aandacht voor concurrentie. Ten tweede kan geïndustrialiseerde en gestandaardiseerde bouw de ontwerpinspanning verminderen, schaalvoordelen realiseren en circulariteit ondersteunen, maar er zijn barrières zoals initiële investeringen en culturele weerstand. Deze thema's zijn geïntegreerd in de adviezen over bundelen, dealflow en samenwerking tussen publieke opdrachtgevers.

De kernoutput is een beslisraamwerk dat context verbindt met advies en vervolgens met contractontwerp. Vijf contextdimensies zijn gedefinieerd en operationeel gemaakt met observeerbare indicatoren: onzekerheid, complexiteit, herhaalbaarheid, het belang van beheer en onderhoud, en schaarse marktcapaciteit. Voor elk advies legt het raamwerk vast of dat advies in een bepaalde context meer waarde krijgt, contraproductief kan zijn, of in het algemeen toepasbaar blijft. Om het raamwerk te gebruiken profileren besluitvormers een project op basis van deze vijf contextdimensies, prioriteren zij de meest relevante adviezen en vertalen die vervolgens naar samenhangende contractkeuzes.

De uiteindelijke adviezen benadrukken het vermijden van private financiering in de meeste V&R-contexten, het geven van prioriteit aan levensduur optimalisatie via geïntegreerde uitvoering, het toepassen van gefaseerde contracten om onbekenden te reduceren, het balanceren van vaste, eenheid en vergoedbare prijzen om flexibiliteit te borgen zonder prijsdiscipline te verliezen, het inzetten van gerichte prikkels,

het investeren in technische expertise aan opdrachtgeverszijde, het bevorderen van langdurige samenwerking, het creëren van realistische dealflow en het stimuleren van standaardisatie en industrialisatie bij publieke opdrachtgevers.

Om van raamwerk naar praktijk te komen zijn drie context archetypen geprofileerd en gekoppeld aan drie illustratieve contractvoorstellen die DBFM-principes combineren met de vier inkoopcomponenten: leveringsvorm, beloningssysteem, selectieprocedure en samenwerkingsmodel. Voorstel 1 is een tweefasen geïntegreerde DBM met een onderhoudshorizon over de systeemlevensduur. Dit voorstel is voor situaties met hoge onzekerheid en hoge complexiteit, waar leren binnen een kleine bundel en focus op levensduur centraal staan. Voorstel 2 is een raamovereenkomst met gestandaardiseerde oplossingen voor sterk herhaalbare assets, met vaste prijzen voor standaardobjecten en eenheidsprijzen voor flexibiliteit en een prestatiegebaseerde rangschikking om de dealflow te bepalen. Voorstel 3 is een budget gestuurde open book portfoliomodel voor omgevingen met beperkte capaciteit en aanhoudende onzekerheid, met target cost en pain gain sharing om interventies economisch te optimaliseren. Dit zijn voorbeeldvoorstellen, hybride vormen tussen de profielen zijn mogelijk.

De studie levert een systematische, contextbewuste route van projectkenmerken naar contractontwerp voor V&R. Het onderzoek gebruikt DBFM als bron van ontwerpprincipes die ook in niet DBFM vormen kunnen worden hergebruikt en laat zien hoe ze operationeel kunnen worden gemaakt met heldere keuzes over levering, prijsstelling, prikkels en samenwerking. In praktische zin helpt het raamwerk publieke opdrachtgevers hun programma te profileren en een doelmatige mix van contractmechanismen te selecteren die V&R-projecten kan ondersteunen.

Het onderzoek is kwalitatief en focust zich op de Nederlandse context; verdere toetsing is nodig om de impact van afzonderlijke adviezen te rangschikken of te kwantificeren. Toekomstig onderzoek zou nader moeten kijken hoe en welke prikkels de doelen van opdrachtgever en aannemer het best kunnen afstemmen. Daarnaast is meer onderzoek nodig naar de meest effectieve bundelgrootte binnen een programmatische aanpak en welke volumes en mate van standaardisatie nodig zijn voor geïndustrialiseerde bouw.

Contents

Abbreviations

Abbreviation	Definition
DB	Design and Build
DBFM	Design Build Finance Maintain
DBFMO	Design Build Finance Maintain Operate
DBM	Design Build Maintain
DMF	Decision Making Framework
ECI	Early Contractor Involvement
EPC	Engineering Procurement and Construction
EPCM	Engineering Procurement Construction and Management
LCC	Life Cycle Cost
O&M	Operations and Maintenance
OECD	Organisation for Economic Co-operation and Development
PFI	Private Finance Initiative
PPC	Public Private Comparator
PPP	Public Private Partnership
PSC	Public Sector Comparator
R&R	Replacement and Renovation
SME	Small and Medium sized Enterprises
SPC	Special Purpose Company
SPV	Special Purpose Vehicle
SQ	Sub-Question

1

Introduction

1.1. Research context

The Netherlands is facing a growing challenge in managing its ageing infrastructure. As infrastructure ages, the need for Replacement and Renovation (R&R) projects becomes increasingly urgent. R&R projects are critical to maintaining the safety, functionality, and sustainability of the country's roads, bridges, tunnels, and other essential infrastructure. It is estimated that the volume and price of R&R works will continue to increase until the year 2100. At its peak, R&R projects will cost €3.7 billion annually, which is 3.5 times as much as has been spent in recent years on R&R projects (Rasker et al., 2023).

Infrastructure owners want to tackle this problem as efficiently as possible. However, traditional contracting models have shown limitations in delivering R&R projects effectively, often resulting in cost overruns, delays, and suboptimal outcomes. Consequently, there is a pressing need for alternative procurement approaches that can enhance efficiency, manage risks effectively, and ensure long term asset performance.

Public Private Partnerships (PPPs), particularly the Design Build Finance Maintain (DBFM) model, offer potential improvements. The DBFM approach integrates design, construction, financing, and maintenance into one contractual framework, theoretically incentivise private partners to optimise lifecycle costs, manage risks effectively, and deliver timely outcomes (J. Koppenjan et al., 2022; Yescombe & Farquharson, 2018). Such integration aligns private sector incentives with public sector goals, potentially driving innovation, performance, and cost effectiveness.

However, despite the theoretical benefits, DBFM contracts have encountered criticism in practice. High transaction costs, rigid contract structures, and inappropriate risk allocation have led to financial challenges and even project failures, reducing their attractiveness among contractors in recent years (Batjargal & Zhang, 2021; Koenen, 2018). Rijkswaterstaat and other asset managers have therefore sought alternative contracting models, such as two phase and portfolio contracts, which promise greater flexibility and balanced risk distribution tailored specifically to the complexity and uncertainties inherent in R&R projects (Rijkswaterstaat & Blom, 2021).

Thus, the question remains: How can the beneficial elements of DBFM contracts be effectively adapted while mitigating their inherent weaknesses, to deliver efficient and resilient R&R infrastructure projects in the Netherlands?

1.2. Problem Statement & knowledge gap

1.2.1. Problem definition

Asset owners in the Netherlands, including Rijkswaterstaat, provinces, and municipalities, face the complex challenge of managing ageing infrastructure portfolios under increasing financial and resource constraints. Ageing assets, combined with heavier usage and evolving functional requirements, heighten the risks of infrastructure failures, safety issues, and diminished service levels (Rijkswaterstaat & Blom, 2021). Compounding these challenges, public organisations often experience shortages in skilled labour and limited budgets, making it difficult to adequately address growing R&R demands.

Public Private Partnerships, particularly DBFM contracts, theoretically provide a viable solution by mobilising private sector capabilities, experience, and innovation. The integration of project phases within DBFM contracts (design, construction, financing, and maintenance) is intended to incentivise contractors toward efficient lifecycle management, risk sharing, and performance optimisation (J. Koppenjan et al., 2022; Yescombe & Farquharson, 2018).

However, existing DBFM frameworks have primarily been applied to new construction projects and have not been extensively tested for the unique complexities of R&R projects, such as hidden structural conditions, unforeseen maintenance requirements, and high levels of uncertainty. Projects such as the Afsluitdijk which can be seen as a R&R have been realised using a DBFM contract. The rigid and inflexible nature of traditional DBFM contracts makes them ill suited to handle these uncertainties, often resulting in increased costs, contractor dissatisfaction, and ineffective project outcomes (Batjargal & Zhang, 2021).

Recent practical experiences highlight significant concerns, including excessively high transaction costs and unbalanced risk allocations that have discouraged private sector participation (Rijkswaterstaat & Wijnen, 2024). Consequently, there is a critical need to explore alternative contractual approaches or adaptations of DBFM principles to better align with the nuanced requirements of R&R infrastructure projects.

1.2.2. Knowledge gap

While Design-Build-Finance-Maintain contracts have been extensively studied in the context of large, one-off infrastructure projects, there is limited research on how the underlying principles of DBFM can be applied in a more flexible or selective manner to address the unique challenges of infrastructure replacement and renovation projects. These projects differ from new construction due to their technical uncertainty, functional continuity requirements, and growing pressure from sustainability goals and budget constraints. Although public-private partnerships (PPPs) have shown potential in delivering integrated and performance-based outcomes, the literature tends to focus on the DBFM model as a complete contract form, rather than as a modular set of design principles that can inform other procurement strategies.

Furthermore, there is a lack of empirical insight into how public clients and private contractors perceive the applicability of DBFM elements in the context of R&R. Especially in the Netherlands, where the majority of upcoming infrastructure work relates to maintaining or renewing existing assets, there is a need for procurement approaches that go beyond traditional models. Current literature does not sufficiently address how DBFM principles might be translated into more adaptable contracting strategies or how these can support learning, innovation, and capacity alignment in public-private collaboration.

This research addresses this gap by exploring how the design principles behind DBFM can contribute to improving the procurement and execution of R&R infrastructure projects. It aims to provide both theoretical insights and practical recommendations for public clients seeking to embed long-term value, collaboration, and performance incentives in non-DBFM contract structures.

1.3. Research design

1.3.1. Research objective

The objective of this research is to explore how the contract principles underlying DBFM contracts can be used to improve the procurement and delivery of infrastructure Replacement and Renovation projects in the Netherlands. Rather than evaluating DBFM as a fixed contract model, this study focuses on understanding how specific elements can address the unique challenges of R&R assignments. By identifying which DBFM principles are applicable and how they can be adapted outside of traditional DBFM structures, the research aims to contribute to more effective contract strategies for public infrastructure procurement.

1.3.2. Research question & sub-questions

Main Research Question:
How can DBFM principles be used to improve contract design for replacement and renovation projects in Dutch infrastructure?

Sub-questions:

1. **What are the scope and characteristics of the Replacement and Renovation tasks?** This question aims to establish the context and scale of the R&R challenges in Dutch infrastructure. It will be answered through a literature review.
2. **What elements does a DBFM contract consist of and what are the contract design principles behind them?** This explores the strengths, weaknesses and design principles behind the DBFM elements. It will also be addressed through a literature review.
3. **Which design principles of DBFM can be used for Replacement and Renovation tasks?** This will be answered through interviews, identifying useful and problematic principles for both clients and contractors.
4. **How can DBFM design principles improve renovation and replacement collaboration?** This will synthesise findings into recommendations for an improved contract design, Furthermore, the advices are translated into a decision making framework which helps public clients decide which contract design is most suited for a specific project context. These advices and decision making framework are validated by an expert review.

1.3.3. Research methods

This study adopts a qualitative research methodology designed to provide an understanding of the Replacement and Renovation challenge in the Dutch infrastructure sector and the advantages and limitations of DBFM contracts. Building on this understanding, recommendations for a new contract approach will be designed using DBFM principles specifically tailored to R&R infrastructure projects.

Before developing this new approach, the R&R challenge and the specific difficulties of applying DBFM principles to such projects must be thoroughly explored. To structure both the problem identification and the solution development, the Double Diamond model is proposed. This model provides a clear framework, separating the research process into two distinct but connected phases: problem identification and solution development (Gustafsson, 2019).

Each diamond consists of two stages: a divergent phase, which involves exploring a wide range of ideas and perspectives, and a convergent phase, which narrows these down to specific, actionable insights.

Figure 1.1 presents the Double Diamond model adapted for this research, along with the four research phases:

1. **Discover:** A literature study is conducted to explore existing knowledge and build a theoretical foundation on the R&R challenge and PPP/DBFM models.
2. **Define:** Semi-structured interviews are conducted to gain in-depth insights into practical challenges and opportunities for applying DBFM principles.

3. **Develop:** Insights from the literature and interviews are synthesised to identify which DBFM principles may be relevant and valuable for R&R projects.
4. **Deliver:** The newly proposed contract approach is refined through expert validation, followed by the formulation of conclusions and recommendations.

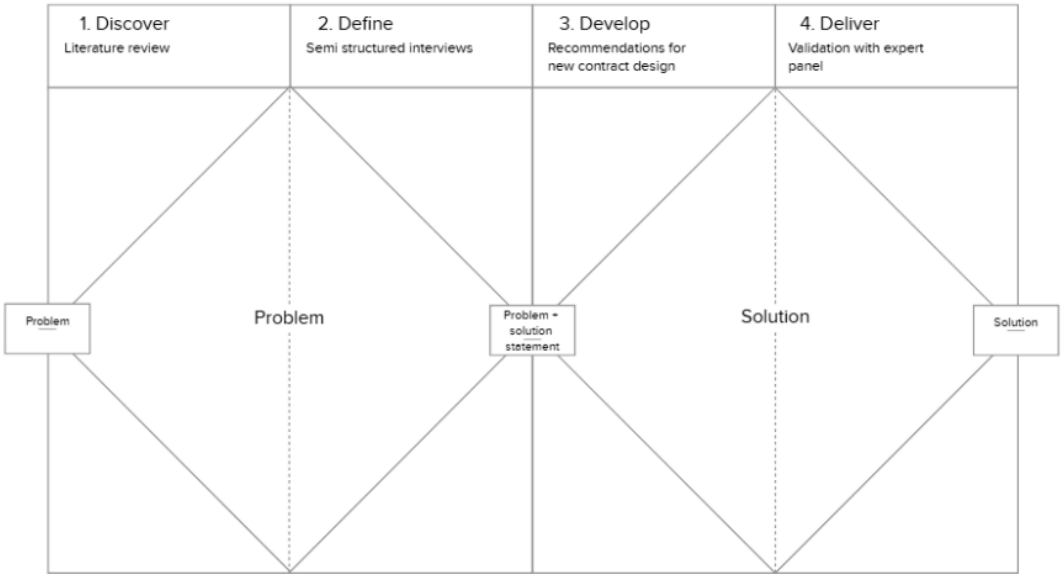

Figure 1.1: Double Diamond research methodology adapted (Own figure).

Literature Review
After introducing the central topic and research questions in in the introduction, The literature review establish a theoretical foundation for this study. The review explores key concepts, best practices, and knowledge gaps concerning Public-Private Partnerships (PPPs), DBFM contracts, and their applicability in Replacement and Renovation infrastructure projects. Based on the findings, a theoretical framework is developed which links the advantages and disadvantages of DBFM contracts to their underlying contract elements. This theoretical framework will be used throughout the rest of the research, particularly as input for the semi-structured interviews.

The literature review aims to answer sub-questions 1 and 2 and to provide the necessary theoretical background for the empirical phase. Keywords such as infrastructure, Public-Private Partnership, DBFM, and Replacement and Renovation were used, both individually and in combination, to search in academic databases including Google Scholar, Scopus, ScienceDirect, ResearchGate, and Elsevier. Literature was assessed based on relevance, citation count, and recency, with priority given to highly cited and more recent publications. The snowball method was used to identify additional relevant sources.

Semi-Structured Interviews and Analysis
To gain in-depth insights into the applicability of DBFM contract elements in the context of R&R projects, semi-structured interviews were conducted with stakeholders from both the public and private sectors. This empirical phase of the research aims to validate the theoretical findings from the literature review, explore differences between theory and practice, and answer sub-question 3.

Two primary perspectives were considered. From the public sector, interviews were conducted with procurement and contract managers from organisations such as Rijkswaterstaat, waterboards, and larger municipalities. These interviews focused on the challenges they face in current R&R projects, and which DBFM elements they find beneficial, ineffective, or even counterproductive. From the private sector, interviews were held with contractors' tender and contract managers to understand which contract characteristics influence their decision to participate in or withdraw from tenders, and which DBFM elements they perceive as valuable or problematic.

Fourteen interviews are conducted to ensure a diverse and representative set of perspectives. Interviewees were selected based on their experience with DBFM contracts and R&R projects. The interviews were transcribed and analysed using qualitative analysis software. Coding was used to identify recurring themes, patterns, and divergent views. This analytical step allowed for a systematic comparison of perspectives between stakeholder groups and contributed to refining the understanding of which DBFM elements are most relevant to R&R projects.

Framework Development and Expert Validation
Building on the literature review and the interview analysis, a decision-making framework (DMF) is developed. The DMF links project context to procurement and contract choices for R&R. The DMF consists of: (i) five context dimensions with a scoring rubric, (ii) an advice $\times$ context matrix with markers (positive, caution, mixed) to signal priority and attention points, and (iii) a translation step from activated advices to contract and collaboration proposals. To make the logic tangible, three illustrative context archetypes (A, B, C) with fitting example types are included.

Given the exploratory nature of the research, the framework is validated through four semi-structured one-to-one expert interviews. The validation tested clarity and completeness of the dimensions and markers, usefulness of the advice mapping, traceability from *context* to *advice* to *contract design*, and practicality in Dutch governance and market conditions.

1.3.4. Research outline

A schematic representation of the research outline, based on the research design described previously, is provided in Figure 1.2. The research is organised into eight chapters structured across four distinct phases: Discover, Define, Develop, and Deliver.

Chapters 1 and 2 form the introductory part of this research. Chapter 1 presents the context, background, and problem definition related to infrastructure Replacement and Renovation. Chapter 2 outlines the research objective, the main and sub-research questions, and the chosen research methodology.

In the **Discover phase**, Chapter 3 provides an extensive literature review addressing sub-questions 1 and 2. It focuses on Public-Private Partnerships (PPP), DBFM contracts, and the characteristics and challenges associated with R&R projects, including an analysis of the strengths and weaknesses of DBFM contracts.

The **Define phase** consists of Chapter 4, which describes the interview methodology, including the data collection process, and Chapter 5, which presents the interview results, analysing DBFM principles that could potentially contribute to R&R projects. This phase addresses sub-question 3.

During the **Develop phase**, Chapter 6 synthesises the insights gained from the literature review and interviews to propose recommendations on integrating DBFM principles into procurement strategies for R&R projects. This chapter directly answers sub-question 4.

Finally, the **Deliver phase** encompasses Chapter 7 and Chapter 8. Chapter 7 provides an expert review to refine and update the proposed contract design based on the synthesis outcomes. Chapter 8 discusses the research findings in detail, addressing the main research question and all sub-questions collectively. It also highlights the research limitations, significance, and provides clear conclusions and recommendations for further research.

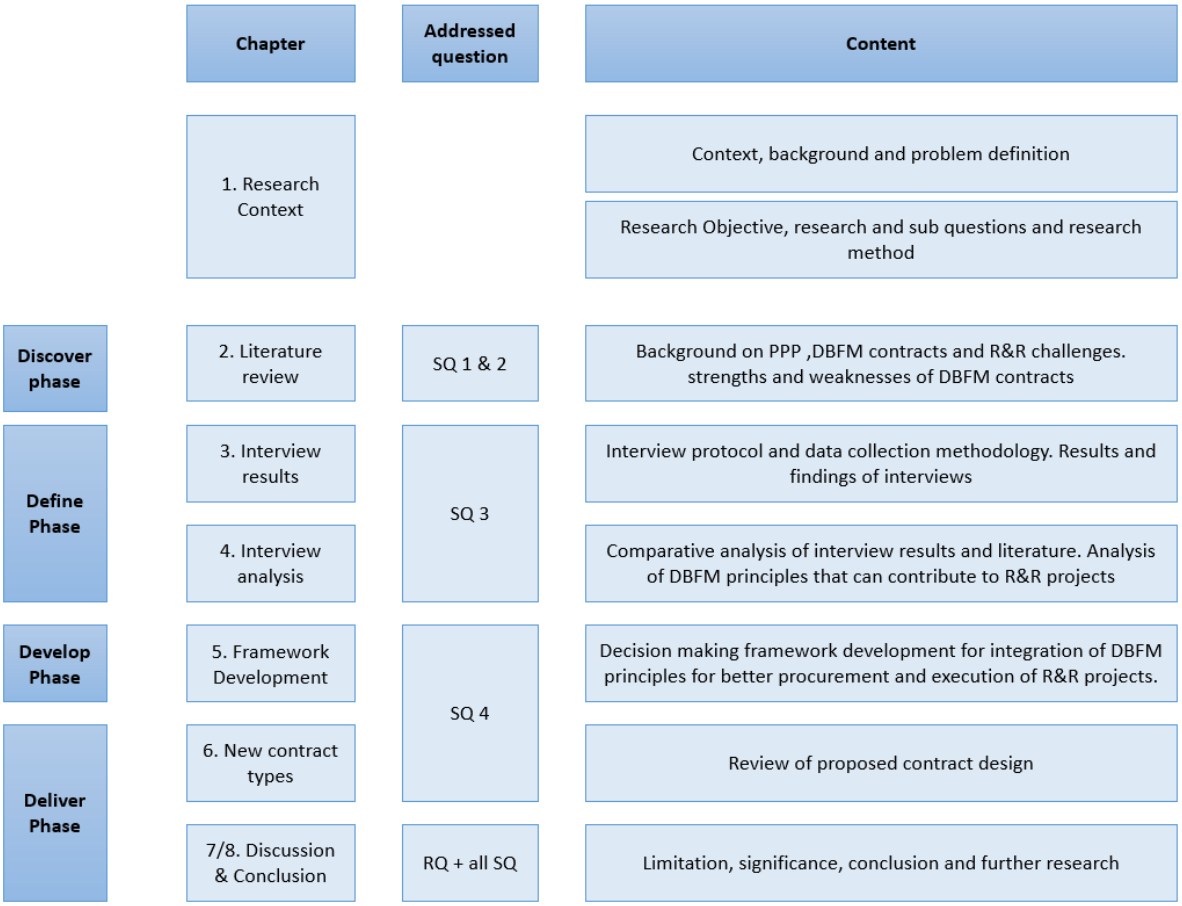

Figure 1.2: Schematic representation of the research outline.

2

Literature review

2.1. Infrastructure Replacement & Renovation Task in the Netherlands

During the population and economic growth after World War II, many European countries rebuilt and upgraded their infrastructures to meet demand (Hertogh et al., 2008; Rasker et al., 2023). In the Netherlands, most post war infrastructure was constructed between the 1960s and 1980s (Rasker et al., 2023). This can be seen in figure 2.1. As a result, in the coming decades many civil assets will reach their technical, economic, or functional lifespan.

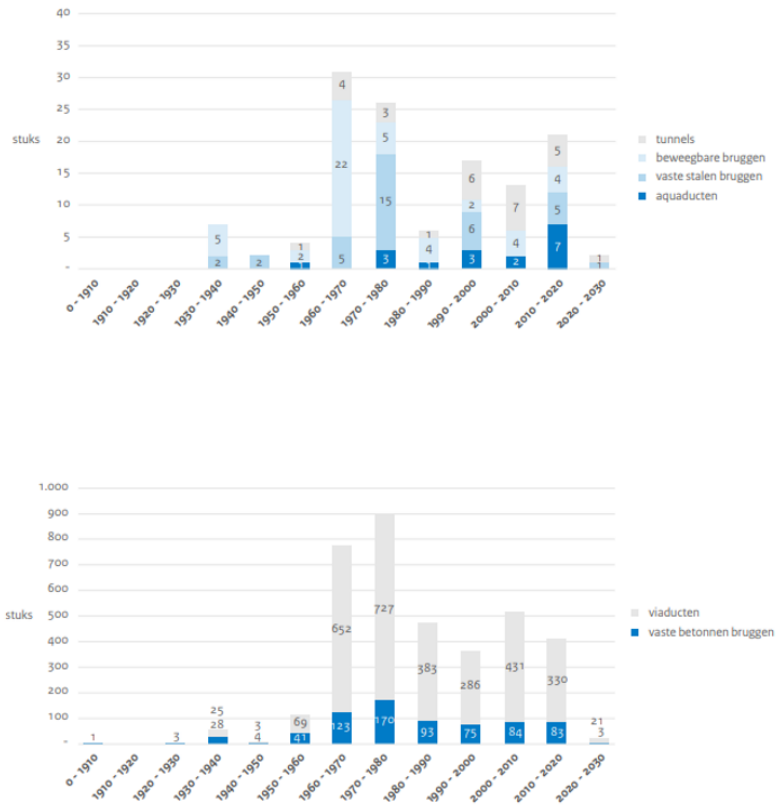

Figure 2.1: Years of construction of civil works HWN (Rijkswaterstaat & Wijnen, 2024)

Because of heavier loads and more intensive use, renovation and replacement are sometimes required sooner than anticipated. This leads to increased management measures to ensure safety, for example, speed reductions and prohibiting truck traffic on bridges. The *Staat van de Infrastructuur (2024)* report also highlights a growing maintenance challenge, noting more disruptions and restrictions on main roads and waterways. Because of these measures, the availability and economic value of the infrastructure declines (Rijkswaterstaat & Wijnen, 2024).

The national administrators Rijkswaterstaat and ProRail, together with 12 provinces, 342 municipalities, and 21 water authorities, jointly manage around 141,000 km of roads, 5,700 km of waterways, 7,000 km of rail, and tens of thousands of structures such as bridges, viaducts, tunnels, locks, weirs, and pumping stations. The total value of Dutch infrastructure is estimated at €347 billion. Municipalities manage over 80% of civil structures in the Netherlands and are thus responsible for most R&R projects in the coming decades (Rasker et al., 2023).

The national forecast for all civil structures, road foundations, and sewer systems shows a significant rise in renewal requirements. Costs are projected to increase from €1.1 billion in 2021 to €2.4 billion annually from 2021–2030, then to €2.9 billion from 2031–2040. From 2040 onwards, annual renewal costs are expected to exceed €3 billion, peaking at €3.7 billion around 2080. Which can be seen in figure 2.2. In the worst-case scenario, costs from 2080–2100 could reach €6 billion per year. In the best case, they remain approximately €2 billion annually. The greatest costs stem from civil structures, rising from €1.5 billion to approximately €2.6 billion by 2080 (Rijkswaterstaat & Blom, 2021).

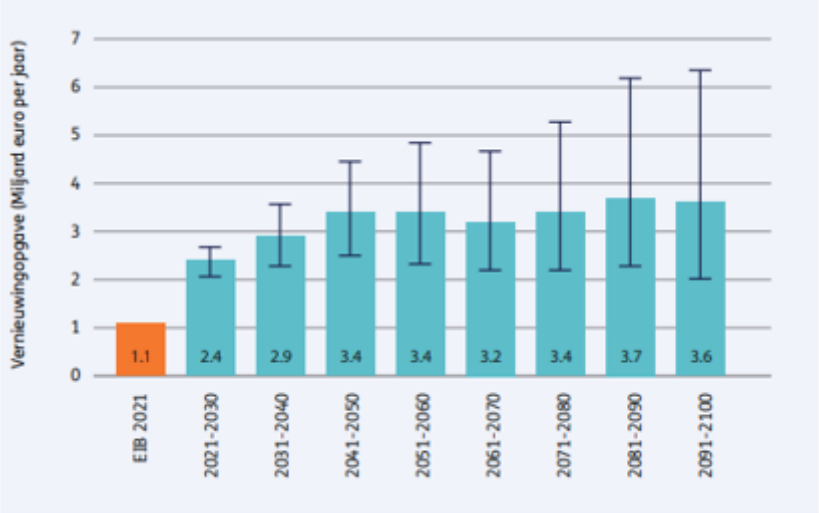

Figure 2.2: Cost forecast replacement renovation from (Rasker et al., 2023)

2.1.1. Maintenance, Renovation, and Replacement

Infrastructure assets inevitably degrade over time. When deciding between maintenance, renovation, or full replacement, asset managers must consider technical, economic, and functional factors. The distinction between these three types of interventions is explained in this chapter.

Lifespan Considerations

An infrastructure asset typically reaches the end of its lifecycle when it no longer meets expected performance or safety standards. This can occur at different moments depending on how its technical, functional, or economic lifespan evolves:

- **Technical lifespan** ends due to material degradation or structural fatigue. For example, road deterioration may reduce user comfort, compromise safety, and increase maintenance costs (Hans Bakker, 2016).
- **Functional lifespan** ends when the asset no longer meets performance requirements due to external factors such as increased traffic, heavier loads, changing regulations, or climate change(Hans Bakker, 2016).
- **Economic lifespan** ends when continued maintenance becomes more costly than renovation or replacement, suggesting it is more efficient to reinvest (Hans Bakker, 2016).

Maintenance

Maintenance refers to actions intended to preserve the current state of infrastructure and delay the onset of serious degradation. According to Horner et al. (1997), the primary aim of maintenance is to reduce or avoid reactive interventions by executing timely, planned tasks. Frangopol (2011) distinguishes three main types of maintenance:

- **Reactive maintenance**, performed after a failure has occurred.
- **Preventive (time-based) maintenance**, carried out at fixed intervals or predefined schedules to reduce the likelihood of failure.
- **Condition-based (predictive) maintenance**, initiated in response to measurable deterioration or condition monitoring indicators.

Preventive maintenance is key for enhancing reliability and minimizing disruptions (Eti et al., 2006). It allows asset owners to identify when interventions are needed before major failures occur. This proactive approach is not only more cost-effective over time but also reduces service interruptions (Thomas & Weiss, 2021).

Renovation

Renovation involves restoring or upgrading infrastructure elements to enhance their technical condition or adapt them to new functional requirements. Unlike maintenance, which focuses on preservation, renovation may involve substantial interventions, such as reinforcing bridge components or retrofitting a tunnel for updated safety standards.

Renovation is often considered when:

- Performance has declined, but structural integrity remains sound.
- New functional requirements arise due to user demands or regulatory changes.
- Replacement is still avoidable but longer-term performance is uncertain.

Hertogh et al. (2008) note that renovation has a greater impact on asset condition than maintenance but less than full replacement. It can also serve as a bridge strategy, extending the life of an asset while postponing major capital investment.

Replacement

Replacement entails full reconstruction or substitution of infrastructure components when the asset can no longer be maintained or renovated efficiently. This often follows the expiration of both technical and economic lifespans and requires careful timing due to its capital intensity and disruption potential(van den Boomen, 2020).

Replacement is typically the most impactful but also the most expensive option. According to Frangopol (2011), optimising the timing of replacement is complex due to various uncertainties:

- Deterioration mechanisms may be hard to measure.
- Societal demands and environmental pressures may change over time.
- Alternatives such as phased renewals, major overhauls, or lifetime extensions may offer interim value.

Ilg et al. (2017) argues that maintenance and lifetime extension should be preferred when uncertainty is high, particularly for infrastructure with long service lives. However, ageing assets eventually require renewal to meet safety and performance standards.

Decision-Making Under Uncertainty

Decision-making across maintenance, renovation, and replacement requires balancing performance, safety, budget, and future uncertainties. According to Atli and Krystallis (2025), managerial flexibility, the ability to adapt future strategies based on evolving conditions, is vital. This includes:

- Monitoring asset degradation and failure rates (Srinivasan & Parlikad, 2013),
- Identifying the drivers of uncertainty (Ilg et al., 2017),
- Evaluating lifecycle costs and performance needs (Frangopol, 2011),

Infrastructure Objectives

As highlighted by Schraven et al. (2011) and others, infrastructure interventions, whether maintenance, renovation, or replacement, must align with five core objectives:

1. **Safety** – Preventing failure and protecting users (Weninger-Vycudil et al., 2015)
2. **Availability** – Ensuring continuous and predictable access (Shami, 2004).
3. **Convenience and Appearance** – Maintaining user satisfaction and visual quality (Schraven et al., 2011).
4. **Quality of Life** – Preserving social and historical value (Thekdi & Lambert, 2013)
5. **Environmental Sustainability** – Reducing ecological impact (Zandvoort & Van Der Vlist, 2019).

Well-designed R&R programmes aim not only to preserve existing value but also to enhance these objectives where possible. The opportunities regarding the R&R challenge are discussed in Section 2.1.1.

R&R opportunities

As infrastructure nears the end of its lifespan, renovation and replacement not only preserve function and safety but also create opportunities. As Hertogh and Westerveld (2010) note, these interventions can upgrade networks for future demands and address economic and environmental challenges. Benefits include:

- Users: Enhanced or new functionalities that adapt to evolving needs.
- Enterprises: Innovative business models, such as energy generating locks or restaurants on bridges.
- Stakeholders: Improved liveability and recreational opportunities.
- Society: More sustainable infrastructure addressing CO_2 reductions, rising sea levels, and nature conservation.

To capitalize on these opportunities, Hertogh and Bakker (2016) emphasize the importance of asset owners adopting a life cycle management approach, which involves:

- Network approach: Redesigning networks for holistic solutions.
- Innovation development: Responding to increasing requirements and budget constraints.
- Adaptive networks: Building flexibility for future challenges.
- Functionality combination: Increasing added value through multifunctional infrastructure.

By renewing multiple co-located networks together, one can achieve cost savings, coordinated spatial development, reduced environmental impact, enhanced economic conditions, and increased societal value (Neef, 2025).

2.1.2. R&R challenges

Uncertainty regarding the state of the existing infrastructure and lack of documentation

Knowledge about the asset's technical and functional performance is difficult to obtain due to poor monitoring systems and precarious information management (Chang et al., 2003; Straub, 2009). This makes it challenging to decide in advance whether renovation or replacement is necessary. Furthermore, infrastructure renewal involves dealing with complex structural systems and all the uncertainties related to the mechanical behaviour of materials (Wang et al., 2021).

Limit disturbance because of the operational system

Prioritizing infrastructure renewal projects efficiently can be a challenge, especially when the operational system of the infrastructure is still in use. Effective decision support systems are required to manage renovation and expansion problems while minimizing disturbance during ongoing operations (Karydas & Gifun, 2005; Shami, 2004).

Managing multiple actors

Multiple stakeholders are involved in and affected by asset management decisions. Therefore, their needs and expectations must be carefully considered (Hertogh & Westerveld, 2010; Schraven et al., 2011).

Because of these challenges, renovation and replacement projects require extensive preparation and investigation in terms of time and resources, contrasting with new construction projects that often have fewer pre-existing constraints.

Constraints not only for R&R but infrastructure in general

- **Scarcity in capacity:** Labour market shortages can limit the output of asset managers and private contractors, particularly as attention and resources are also demanded by other urgent societal challenges such as the energy transition and housing shortage (Rijkswaterstaat & Blom, 2021).
- **Budget constraints:** Budget restrictions can limit the volume of projects and hinder sustainability and innovation goals due to the tight budgets available for renewal projects. Elected officials are often reluctant to support infrastructure renewal projects because of high and uncertain direct costs, budget constraints, and lack of political incentives. These issues can result in inadequate maintenance of existing infrastructure systems, over-investment in inefficient new systems, and an inability to achieve optimal use of existing facilities (Rijkswaterstaat & Wijnen, 2024).
- **Environmental regulation:** In the Netherlands, strict nitrogen regulations have become a constraint for infrastructure projects. Construction activities that emit nitrogen compounds face delays or restrictions due to legal and ecological thresholds. This complicates planning and permitting procedures and can impact the feasibility and timeline of replacement and renovation projects (Rijkswaterstaat & Wijnen, 2024).

2.1.3. Programmatic Approach of Infrastructure Renovation and Replacement

In the context of infrastructure renewal and replacement (R&R), programmatic management is increasingly adopted as a response to growing complexity, resource constraints, and the need for long-term value creation. Traditional project-based approaches often struggle with fragmentation, limited innovation, and poor knowledge transfer. Programmatic management offers a way to coordinate related projects and achieve benefits that cannot be realised through isolated project execution (Eweje et al., 2012; Pellegrinelli, 1997).

Programmes are especially relevant where there is an opportunity to bundle repetitive tasks to manage scarce resources such as skilled labour and raw materials, and align infrastructure investments with broader strategic goals. By facilitating economies of repetition, programmatic approaches can reduce transaction costs, enhance predictability, and support continuous improvement (Van De Waerdt et al., 2024).

Programmatic Management

Programmatic management refers to the integrated coordination of multiple related projects that are executed either sequentially or concurrently, aligned under overarching strategic objectives (Martinsuo & Ahola, 2022). According to Shehu and Akintoye (2009), it is "an integrated structured framework that coordinates, aligns and allocates resources, and plans, executes, and manages related projects to achieve optimum benefits that cannot be realised if managed separately."

Effective programme management enhances innovation, facilitates inter-project learning, and promotes strategic alignment (Arnoldussen et al., 2017) (Lycett et al., 2003). These characteristics make it particularly valuable in infrastructure sectors where complexity and repetitiveness intersect.

Differentiating Management Approaches

To appreciate the benefits of programmatic management, it is essential to distinguish it from project management, portfolio management, and multi-project management. These concepts vary in purpose, structure, and strategic value (Shehu & Akintoye, 2009).

Project Management focuses on executing individual, temporary endeavours aimed at delivering specific outputs. Projects are characterised by a defined scope, schedule, and budget (Nicholas & Steyn, 2012). In infrastructure, this might include the construction or renovation of a single bridge or tunnel.

Programme Management organise related projects to achieve overarching goals. Unlike projects, programmes are dynamic, often dealing with evolving scopes and stakeholder needs. Control mechanisms emphasise benefit realization and adaptability (Lycett et al., 2003).

Portfolio Management groups projects and programmes to ensure alignment with organisational strategies and resource optimisation. Projects in a portfolio need not be related but are evaluated collectively to maximise value (Thiry, 2002).

Multi-Project Management coordinates multiple independent projects that share resources but are not strategically aligned. The focus is on operational execution and conflict avoidance, distinct from the strategic orientation of programmes (Martinsuo & Ahola, 2022).

Benefits and Barriers of Programmatic Approaches

Programmatic approaches are especially suited to repetitive R&R tasks in infrastructure. Bundling projects promotes economies of repetition, reduces transaction costs, and enables more predictable scheduling (Tomczak & Jaśkowski, 2022).

Contractors and clients gain experience and learn across similar projects, leading to improved efficiency and innovation (Arnoldussen et al., 2017). According to Brady and Davies (2004), this bundling fosters continuity, knowledge exchange, and process optimisation.

Moreover, programmatic management supports:

- Long-term collaboration and trust (Bresnen & Marshall, 2000),
- Cross-project learning and knowledge transfer (Geraldi et al., 2022),
- Strategic alignment and shared goals (Vosman et al., 2023).

However, potential barriers include:

- Reduced market competition due to large project bundles (Estache & Iimi, 2011)
- Scheduling inflexibility in repetitive tasks (Hegazy & Wassef, 2001).

Governance in Programmatic Management

Programme governance must accommodate ambiguity, diversity, and evolving stakeholder interests. Unlike project governance, which emphasizes compliance with predefined goals, programme governance is adaptive and strategic (Shehu & Akintoye, 2009).

Relational governance, which relies on informal coordination and trust, is critical. It aligns actors around shared objectives that transcend traditional project KPIs like time and budget (Vosman et al., 2023).

Effective programme governance includes:

- Adaptive leadership structures, Leadership in a programme must be flexible and capable of responding to changing circumstances, priorities, and stakeholder needs.
- Incentive alignment, all stakeholders should have incentives that are consistent with the program's overall objectives.
- Mechanisms for joint decision-making, this refers to formal or informal structures that ensure all key stakeholders participate in important decisions, fostering collaboration and shared accountability.

2.1.4. Industrialised Construction for Renovation and Replacement

Industrialised construction refers to the application of manufacturing principles such as standardisation, modularity, off-site prefabrication, automation, and process integration to the construction industry. It aims to optimise key performance dimensions including cost, time, quality, environmental impact, and safety (Gann, 1996; Lawson et al., 2011). As infrastructure assets increasingly face renewal and replacement (R&R) demands, industrialised construction offers an opportunity to improve efficiency, manage repetitive tasks more effectively, and reduce lifecycle costs.

In infrastructure R&R, industrialised approaches address sector-wide challenges such as labour shortages, growing sustainability demands, and fragmented supply chains. Compared to conventional construction, industrialised construction enables systematic planning, control, and continuous improvement throughout the asset lifecycle (Kamali & Hewage, 2015). Industrialised construction can be seen as a new way of working which is enabled by a more programmatic approach of repetitive work.

Characteristics of Industrialised Construction

Industrialised construction refers to a set of technologies and practices rooted in manufacturing systems (Lessing & Brege, 2017). Its key features are: standardisation of components and processes; modularisation and predefined building systems; off-site manufacturing and pre-assembly; integrated design, planning and operations; and continuous improvement supported by digital tools. Using prefabricated components and modular systems enables repetitive, scalable and quality-assured delivery, which is particularly well suited to infrastructure programmes with many similar assets, such as bridges and viaducts.

Industrialised construction can integrates several features:

- **Prefabrication:** Structural and technical elements are manufactured in factory-controlled environments, reducing on-site activities and improving quality assurance (Kamali & Hewage, 2015).
- **Modularization:** Standardised modules enable faster on-site assembly, minimising construction time and labour intensity (Kamali & Hewage, 2015).

- **Standardisation:** Repetitive use of uniform components reduces design complexity and allows for economies of scale (Kauppinen et al., 2024).
- **Digitalization and BIM:** Advanced data tools support coordination, traceability, and lifecycle asset management, enabling higher predictability (Lessing & Brege, 2017).

These characteristics help transform the construction from a project-based undertaking into a product-based system.

Benefits for Infrastructure R&R

The repetitive nature of many R&R activities makes industrialised construction applicable when these activities can be standardised. Key benefits include:

- **Increased Speed:** Projects leveraging modular and off-site approaches can achieve time savings of up to 50% (Jaillon & Poon, 2010).
- **Cost Efficiency:** Reduced labour needs, minimised waste, and streamlined supply chains lower overall costs (Blismas & Wakefield, 2009).
- **Improved Quality and Safety:** Controlled manufacturing environments enhance build precision and reduce on-site hazards (Chen et al., 2009).
- **Environmental Performance:** Prefabrication reduces emissions, noise, and construction waste, contributing to sustainability goals (Cheng et al., 2023).

Barriers and Challenges

Despite its benefits, several barriers constrain widespread adoption:

- **High Initial Investment:** Setting up prefabrication and digital systems requires significant capital (Mao et al., 2013).
- **Design Inflexibility:** Industrialised systems often require early design finalisation, conflicting with traditional iterative design practices (Lu & Liska, 2008).
- **Cultural Resistance:** Construction actors accustomed to on-site, bespoke methods may resist standardisation and new technologies (Chiang et al., 2005).
- **Fragmentation and Coordination Gaps:** Horizontal and vertical fragmentation of responsibilities in construction hinders integrated planning (Mansoori et al., 2024).

Overcoming these challenges requires systemic change across the whole ecosystem of stakeholders. Furthermore, it is only beneficial if there is enough repetitive work that can be standardised for the initial investments to be paid off.

2.2. Public Procurement

2.2.1. Public Client Organization

In infrastructure replacement and renovation (R&R) projects, the role of the public client is pivotal. As infrastructure ages and societal demands evolve, public sector organisations must ensure that their commissioning practices align with both technical objectives and public values. Unlike private clients, who primarily pursue profit, public clients are tasked with delivering long-term societal value, ensuring transparency, and being accountable to taxpayers (Morledge & Smith, 2013; Winch, 2009).

According to the Economic Co-operation and Development (OECD), a construction client is defined as "a natural or legal person for whom a structure is constructed, or alternatively the person or organisation that took the initiative of the construction" (Eurostat, 2013). In the public sector context, this role extends beyond functional commissioning. It includes strategic alignment with democratic mandates, ensuring value for money, and engaging with a complex web of stakeholders including users, contractors, and the wider public (Eisma & Volker, 2014).

Kuitert (2021) distinguish three relational dimensions of public clients:

- **Client–stakeholders**: engaging civil society, interest groups, and regulatory bodies.
- **Client–users**: understanding and integrating user needs and satisfaction.
- **Client–contractors**: shaping contractual and operational dynamics in project delivery.

This research focuses primarily on the client–contractor relationship.

Public Sector Objectives and Strategic Role

Public clients operate under a different strategic logic than private clients. Their objectives often include: ensuring value for money, promoting social equity and inclusion, supporting environmental sustainability, and guaranteeing accountability and transparency (Haugbølle & Boyd, 2013; Morledge & Smith, 2013). Unlike private organisations, where strategic decisions are made internally, public clients operate within a political framework where objectives are often externally imposed by elected bodies (Winch, 2009). This means public-sector discretion is constrained and subject to public scrutiny, making decision-making processes more complex and politically sensitive (Kuitert et al., 2018).

Private sector	Public sector
Profit level	Accountability
Improved financial ratios	Transparency
Efficiency	Social involvement
Productivity	Democratic decision
Market position/share	Equity
Increased dividend	Fairness
Customer retention	Employee welfare
Customer satisfaction	Reduced complaints
Corporate governance	Effective service
Corporate social responsibility: employee welfare/environment/community	Reduced staffing levels
Value for money	Benchmark targets

Figure 2.3: Strategic aims in public and private sector organisations from (Boyd & Chinyio, 2006)

Commissioning and Collaboration

In collaborative infrastructure delivery, commissioning is the process by which public clients define and manage their interface with the market. It involves shaping the procurement, contract, and oversight mechanisms to ensure effective outcomes. Boyd and Chinyio (2006) and Hughes et al. (2006) note that integrated contracts require the client to focus on defining performance outcomes rather than prescriptive inputs.

Quality assurance in this setting focuses on managing processes rather than inspecting end-products. Clients establish functional requirements and performance indicators, allowing private contractors to propose design and execution solutions that meet these goals (Boyd & Chinyio, 2006).

In contrast, in traditional contracts such as Design-Bid-Build (DBB), the public client plays a more directive and segmented role. The client is responsible for developing detailed designs and specifications upfront, which are then tendered to a contractor for execution. This means the client must invest in significant internal technical capacity or rely on external consultants.

This highlights how different forms of commissioning and collaboration impact the capacity demands and skillset requirements of the public client.

2.2.2. Procurement theory

In construction management literature and practice, the client's contracting and procurement strategies are considered crucial for fostering collaboration among project actors. According to Eriksson (2017), four core procurement strategy components can be distinguished:

- the delivery system
- the reward system
- the contractor selection procedures
- the collaboration model

These components can be strategically combined to develop a governance structure that aligns with the specific characteristics of a project. These components also influence the decision of contractors to bid or not to bid on a tender.

The delivery system

Traditional approaches such as Design-Bid-Build (DBB) separate design and construction phases, often resulting in fragmented responsibility and limited integration. In contrast, integrated systems such as Design-Build (DB) and Design Build Finance Maintain (DBFM) promote early contractor involvement, allowing private actors to contribute their knowledge during the design phase, potentially leading to innovative and cost-effective solutions (Eriksson, 2017).

Reward Systems

Fixed-price contracts are widely used in the procurement of DB and DBB, primarily because they allow the client to minimise investment costs through competitive tendering (Eriksson, 2017). However, such arrangements can weaken collaboration, as contractors may be incentivised to cut costs, potentially compromising quality. In contrast, incentive-based reward systems, such as cost savings sharing or performance-based bonuses, can improve motivation for joint development and innovation (Rose & Manley, 2010). These mechanisms are especially effective when contractors are involved early, as they foster a sense of ownership and long-term commitment to the project's goals.

Contractor Selection Procedures

Contractor selection often followed a lowest-bid tendering model, which is suitable for low-risk, well-defined projects where qualifications play a minor role. However, in complex projects with higher uncertainty, this approach may lead to suboptimal outcomes. More recently contractors are awarded a project based on best price quality ratio (Beste prijs-kwaliteit verhouding BPKV). Alternative models that involve pre-qualification and multi-criteria selection taking into account organisational competence, experience, and past performance can enhance collaborative dynamics and promote innovation (Kadefors et al., 2007; Volker & Rose, 2012). According to Eriksson (2017), selecting a contractor who is both competent and willing to engage in joint development work can significantly improve project performance.

Collaboration Models

Collaboration models define how the public client and contractors work together. Traditional models often result in hierarchical and transactional relationships. However, more collaborative models, such as alliances or framework agreements, enable shared decision-making, transparency, and joint problem-solving. These models are particularly effective when paired with early contractor involvement and

incentive-based payment systems, as they encourage long-term trust and continuous performance improvement (Eriksson, 2017).

In other literature the delivery system combined with the collaboration model is called the project delivery model. The delivery method defines the way in which tasks, responsibilities and risks are distributed between the parties involved in a project. The project delivery method is influenced by three decisions: the degree of (1) bundling (assignment consisting of one or a combination of (similar) projects/activities, e.g., framework agreement or programme contract), (2) integration (is the market party only involved in execution or also in design, maintenance and/or operation), and (3) risk allocation (are risks transferred to the market or shared between public and private entities such as with alliances) (Hermans, 2022).

These three components all influence the procurement strategy of public clients and the choice of these components is influenced by the public client's objective and the type of assignment, as well as the public client's capabilities and the available market capacity (Suprapto et al., 2014). On the basis of these decisions, the procurement procedure and the content of the contract are then determined.

2.3. Contractor Perspective

Understanding how contractors assess tenders is essential for designing effective public procurement strategies in construction. Contractors make bid/no-bid decisions based on a complex trade-off between different factors (Slockers, 2019). Firstly, they determine whether the project fits within their strategic and operational context for example, whether it aligns with their existing portfolio, whether they have the right expertise available, and whether the planning fits within their current workload. After this initial strategic fit assessment, contractors weigh the specific tender-related trade-offs. These factors can be categorized into four main areas: expected tender costs, chance of winning, project risks, and expected project rewards, as illustrated in Figure 2.4. These factors are directly influenced by procurement strategy components such as the delivery system, pricing mechanism, tender duration, selection method, and contract conditions.

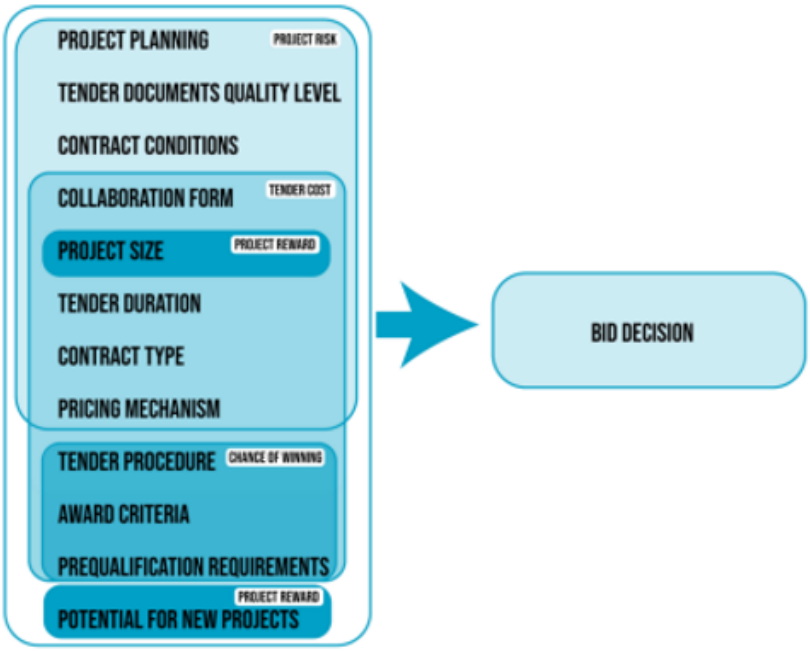

Figure 2.4: Factors influencing bid decision from (Slockers, 2019)

Tender Costs

Contractors weigh the effort and cost required to prepare a competitive bid. Integrated delivery systems, such as DBFM, generally entail higher tender costs than traditional DBB models, particularly when significant design work is required during the tender phase (Volker & Rose, 2012). While such investments are acceptable in large or complex projects with long-term returns, they can deter participation in smaller tenders. Additionally, short tender durations can inflate costs by requiring more personnel in a shorter time frame, reducing bid efficiency. Fixed-price contracts further increase preparation costs, as contractors must invest more in risk analysis and cost forecasting under this pricing mechanism (Eriksson, 2017).

Chance of Winning

The perceived chance of winning is another major consideration. Contractors are less likely to participate if more than three competitors are pre qualified, as this reduces their expected return on tender investment. In current market conditions, many contractors prefer restricted procedures with fewer competitors and clearer selection criteria. Moreover, if pre qualification requirements are overly strict or unclear, they can eliminate otherwise capable contractors from the pool and result in widespread no-bid decisions (Slockers, 2019).

Project Risks

Contractors assess project risks based on both the contract documents and the delivery system. For example, unclear tender documents or ambiguous project scopes may increase uncertainty and inflate bids through risk premiums. Specific contract clauses, such as unlimited liability or transfer of uncontrollable risks, can strongly deter bidding. These risks are especially significant in fixed-price contracts, where financial uncertainty is highest for the contractor (Kadefors et al., 2007). Finally, project planning requirements such as tight deadlines and limited tender preparation time may increase the risk profile beyond what contractors are willing to accept (bouwcampus, 2023).

Project Reward

Contractors expect that rewards will be proportionate to the size, complexity, and risk of a project. If ceiling prices are imposed and set too low, the financial viability of a project becomes questionable, leading to no-bid decisions (Slockers, 2019). Non-financial rewards may also factor into contractor decisions, particularly if the project offers opportunities for future work or enhances reputation within the client's portfolio. As such, long-term collaboration models, especially those with performance-based incentives or frameworks for repeat business, can make tenders more attractive, even when short-term margins are limited (Rose & Manley, 2010).

2.4. DBFM Contracts

Public-Private Partnerships (PPPs) have been widely adopted worldwide to deliver public works such as infrastructure (McQuaid & Scherrer, 2010). PPPs is an umbrella term encompassing different contract types. Some characteristics of PPPs are that they entail long-term contracts between public and private parties. In these contracts, risk is transferred from public entities to private companies, and private capital is attracted to (partly) fund the project. Furthermore, PPPs make use of integrated contracts, which make the private contractor responsible for more than just construction. In contrast, traditional contracts involve tendering and awarding design, construction, and maintenance separately to different companies. The Organisation for Economic Co-operation and Development (OECD) defines PPPs as "long-term contractual arrangements between the government and a private partner whereby the latter delivers and funds public services using a capital asset, sharing the associated risks" (Centre, n.d.).

There are two main forms of PPP to distinguish: the concession model and the alliance model.

2.4.1. Alliance PPP

The alliance PPP is based on an equal partnership between parties and is focused on jointly establishing and executing a project. In this form, the risk is shared and the project is defined collaboratively. This model relies heavily on trust and cooperation to create synergies. A notable example of an Alliance PPP in the Netherlands is the Waaldijk Gorinchem-Waardenburg reinforcement project, executed as part of the national Flood Protection Programme (HWBP). This project adopted an alliance structure to jointly tackle uncertainties and optimize solutions collaboratively between the regional water authority (Waterschap Rivierenland) and private partners. Central to the project's success were shared objectives, open communication, and a focus on joint risk management and innovation (Cobouw, 2021; HWBP, 2021).

2.4.2. Concession PPP

In the concession model (or concession-based PPP), various components of a construction project are assigned by the client to a single contractor. An important aspect is that private parties are required to contribute financially to the project. Furthermore, the concession model focuses on the traditional roles of government and private parties in maintaining a client–contractor relationship with defined responsibilities and risks transferred to one of the parties.

In the concession model, the collaboration is formal and based on rules and explicit agreements (contracts), whereas in the alliance model, the focus is on softer factors such as mutual trust and similar elements (Reynaers, 2013). The question, therefore, is whether, in the concession model, a collaboration can be established that goes beyond a purely contractual relationship (Verhees et al., 2015), in order to achieve the intended added value and synergy.

In the Netherlands, the most used form of Public-Private Partnerships for infrastructure projects is the concession model with a Design, Build, Finance, and Maintain (DBFM) contract. In this type of contract, the design, construction, and maintenance phases are integrated into one contract and awarded to a consortium. This consortium is also responsible for financing the project.

An example of a Concession PPP using a DBFM contract is the A9 Gaasperdammerweg motorway expansion. Rijkswaterstaat awarded this project to the IXAS consortium, which was responsible for the design, construction, financing, and maintenance phases integrated into one long term contract. Key advantages included lifecycle optimisation, innovative engineering solutions, and efficient risk allocation. However, the project also highlighted typical DBFM challenges, such as rigid contractual structures and high complexity in managing financial risks (EIB, 2021; Rijkswaterstaat, 2021)

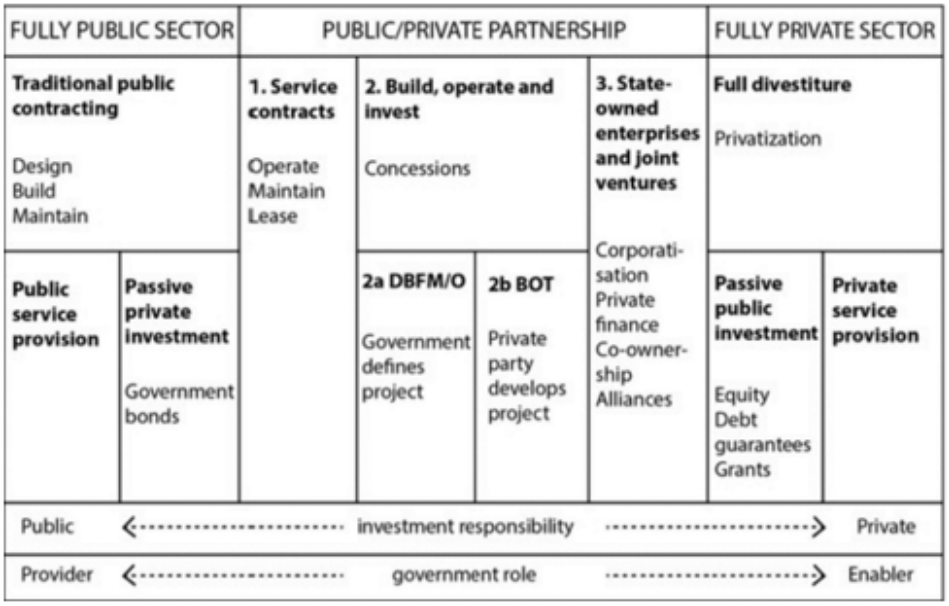

Figure 2.5: different types of contracts from (Verhees et al., 2015)

2.4.3. History of PPP

Public-Private Partnerships have roots dating back centuries, but their modern form emerged in the late 20th century as governments sought innovative ways to address infrastructure deficits while managing fiscal constraints. The UK played a pioneering role in the 1980s and 1990s with its Private Finance Initiative (PFI), which inspired many countries to adopt PPP models. The model emphasised the political trend to minimise public bodies and expenditures and make use of the more efficient private sector (Verweij & Satheesh, 2022). In the Netherlands, PPP was adopted around the 2000s with the DBFM infrastructure project The A59 the first ever road DBFM in the Netherlands. Currently, the most recent project using a DBFM contract is the Via15 project around Arnhem.

2.4.4. Reasons for Adopting PPP

Initially, the main reason for adopting PPP was the financial added value brought about by the private financing of public projects during times of limited public funds. More recently, however, other motivations have emerged.

Aziz (2007) distinguishes between finance-based PPPs and service-based PPPs. This distinction has important implications for the structure and design of PPPs. In a finance-based PPP, the primary issue is a shortage of public funds. In this case, while private financing can provide the necessary capital, it cannot be fully covered by government budgets. The investment must instead be recouped through tolls or other user-generated revenue. Thus, private financing is repaid through private economic exploitation.

In contrast, in a service-based PPP, the government retains control of project funding and provides performance-based payments to the private consortium. These payments are tied to meeting defined service levels. The investment is therefore repaid from the public budget during the operational phase. This model is only feasible if the government maintains a long-term financial commitment.

In the Netherlands, public financial constraints were not the main motivation for adopting the PPP model. Consequently, Dutch PPPs are generally considered service-based. The Dutch government uses a Public-Private Comparator (PPC) and a Public Sector Comparator (PSC) to determine whether a DBFM(O) contract offers added value compared to a Design & Construct (D&C) contract (OECD, 2008).

These comparators assess value for money, a key principle in PPPs. Grimsey and Lewis (2004a) define value for money as:

> "The optimum combination of whole-of-life cycle costs, risks, completion time and quality in order to meet public requirements."

This principle is central to the decision to adopt PPPs and DBFM contracts.

The following are key reasons for adopting PPPs and DBFM contracts in the Netherlands:

- Potential for a better price–quality ratio of the infrastructure over its entire lifecycle.
- Potential for accelerating the realization of infrastructure projects.
- Potential to increase the volume of infrastructure projects when public funding is limited (der Staten-Generaal, 2019; Verhees et al., 2015).

Motivations for PPP have also included improved efficiency, risk transfer to the private sector, and reduced public budget and borrowing pressures (McQuaid & Scherrer, 2010). For example, the European PPP Expertise Centre identified value for money as the most important motivation behind the use of PPPs (Centre, 2015).

2.4.5. Characteristics and Elements of DBFM

Private Financing in DBFM

In DBFM contracts, the private consortium finances the project upfront and needs to recoup its investment during the operational and maintenance phase (J. Koppenjan et al., 2022). To finance the design and construction, it must obtain loans from banks and equity from private investors. During the operational and maintenance phase, the Special Purpose Vehicle (SPV) receives payments for the services provided these are usually availability-based. With these periodic payments, the SPV can pay its maintenance subcontractor, repay the loans, and distribute dividends to its shareholders(Verweij et al., 2019).

This means that, in contrast to publicly funded models such as traditional contracts or D&C, financing risk is shifted to the private consortium. This means that they have to involve banks and equity investors, who are generally risk averse and require rigorous risk management (Demirag et al., 2011). This is expected to contribute to better risk identification, allocation, and mitigation, and, as a consequence, improved cost performance (on-budget delivery) and time performance (on-time delivery) (J. Koppenjan et al., 2022; Verweij & Van Meerkerk, 2020).

However, because private financing induces risk-averse behaviour, it can have a negative effect on innovation development, leading to innovation being mostly incremental in nature (Hueskes et al., 2016).

The future cash flows of the project must be enough to fund project construction, maintenance&operating costs, and debt payments in the form of interest, while also providing returns to shareholders (Engel et al., 2010; Sarmento & Renneboog, 2015).

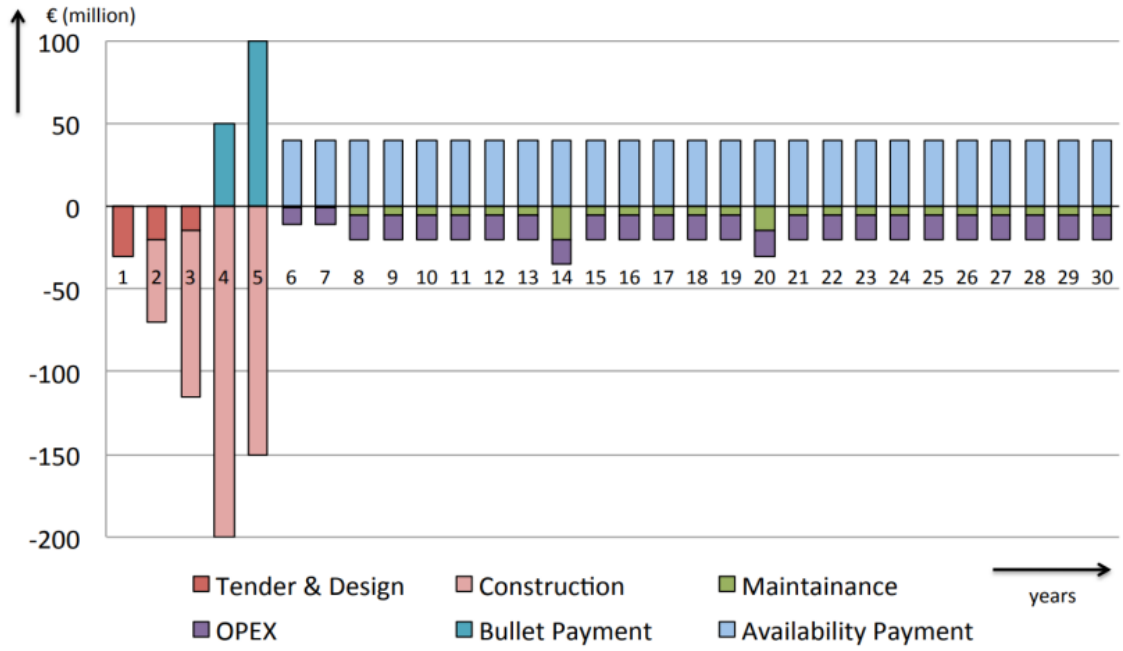

Figure 2.6: Cash flows in a DBFM project (Damen, 2019)

Performance-dependent payments

Cash flow in a PPP project is generated through payments to the private consortium, either by users (in toll-based models) or by governments (in availability-based models). Outside of the Netherlands private consortia often recoup their investments by collecting tolls from road users such as toll for highways or tunnels. This is called usage-based payments (J. Koppenjan et al., 2022).

In the Netherlands, given factors such as a dense road network and limited budget pressure, payments to the private consortium are tied to service performance, most of the time availability based remuneration. This means that in contrast to traditional D&C contracts where performance based payments usually apply only during construction. Thus, once the project is delivered, payments stop, so there is no financial incentive to sustain high quality in maintenance and operation (J. Koppenjan et al., 2022).

In DBFM, if infrastructure is unavailable, for example, due to repairs or regular maintenance, the private partner receives reduced or delayed payments, negatively impacting its profit. This creates a strong incentive to build high-quality infrastructure that requires fewer repairs and less maintenance.

This mechanism is expected to lead to better quality performance (in terms of durability and road safety) (Albalate & Bel-Piñana, 2019; Lenferink et al., 2012), and positively influence time performance, as payments are linked to the timely achievement of milestones (Verweij et al., 2019).

Furthermore, because the requirements are also performance-based, this allows for innovative designs which can increase efficiency and sustainability.

Integrated Contracts

In DBFM contracts, various project phases that were traditionally contracted separately, such as design, construction, and maintenance, are now integrated into one contract and awarded to one consortium (J. Koppenjan et al., 2022). Both D&C and DBFM are integrated contracts, but only DBFM includes the maintenance phase (Lenferink et al., 2012). Because of the integration of the maintenance phase the consortium is incentivize to think about and implement life cycle cost optimization (J. Koppenjan et al., 2022).

This integration implies that during the design and construction phases of the project, additional investments may be made in higher-quality infrastructure. These upfront investments result in lower

maintenance needs and better long-term performance. Bundling also means that design, construction, and maintenance processes can be cleverly combined and parallelized, saving time and costs (Lenferink et al., 2012).

Because lifecycle optimisation requires innovative, smart and new solutions, bundling is said to stimulate innovation. In DBFM contracts, which emphasise output-based performance such as availability and safety, the contractor is encouraged to provide innovative solutions to meet these specifications. Lewis (2021) explains this as providing "enhanced opportunities and incentives for bidders to fashion innovative solutions to meet those requirements."

Risk Transfer

In DBFM contracts the risks related to all stages of the project thus: design, constructiion, financing, and maintaining are transferred from the public to the private partner. In addition to these phase-specific risks, the responsibility for managing the interphase between phases is also transferred. Meaning the private consortium carries a lot of risks (Verhees et al., 2015).

As a result, the DBFM model is sometimes called the "Bahamas Model" (J. F. Koppenjan, 2005), reflecting how the public client is largely relieved of management responsibilities. Since the government procures a service rather than the execution of specific tasks, it focuses on performance monitoring, in Dutch infrastructure primarily related to road availability and safety (J. F. Koppenjan, 2005).

It is assumed that private actors, under pressure from their financiers, are better equipped to manage risks effectively. Therefore, DBFM is expected to reduce cost and time overruns, improve quality performance, and lower the chance of overall project failure (Flyvbjerg, 2009).

Long term collaboration

When DBFM contracts are collaboratively managed, they tend to result in better performance. Collaboration supported by relational governance builds trust, which encourages actors to share risks and resources, be receptive to each other's problems, and seek joint solutions (Ghobadian et al., 2004; Huxham & Vangen, 2013).

Although collaboration can enhance the performance of traditional contracts too, the long-term and integrated nature of DBFM projects amplifies these effects. Tasks that were previously separated among actors are now executed collectively over a longer period (Steijn et al., 2011).

A downside of long term collaboration can be that it will lead to higher transaction cost. Although collaboration may lead to higher transaction costs, it also creates collaborative advantages, such as improved cost, time, and quality performance. It also fosters trust and encourages innovation (Warsen et al., 2019).

Governance

In DBFM projects, the contractor is a consortium of companies that together form a Special Purpose Company (SPC). This consortium typically includes construction firms and private investors. The SPC acts as the contractor for the public client, such as Rijkswaterstaat, and is also responsible for arranging project financing. To do this, the SPC takes out long-term bank loans, which are supplemented with equity from shareholders. Banks receive interest payments on their loans, while investors earn dividends on their shares (Yescombe & Farquharson, 2018).

The SPC enters into subcontracts with two primary entities:

- An Engineering, Procurement, and Construction (EPC) company for the design procurement and construction of the infrastructure;
- A Maintenance (MTC) company for long-term maintenance, operation and upkeep.

In some projects, a single EPCM contract is signed that includes design, construction, and maintenance under one umbrella (Wijnker et al., 2019).

The contractual structure allows the special purpose company to pass risks down to subcontractors, preventing them from reverting to financiers. Equity investors and lenders therefore seek to keep risk at the contractor level or to pass it back to back to subcontractors. (Yescombe & Farquharson, 2018)

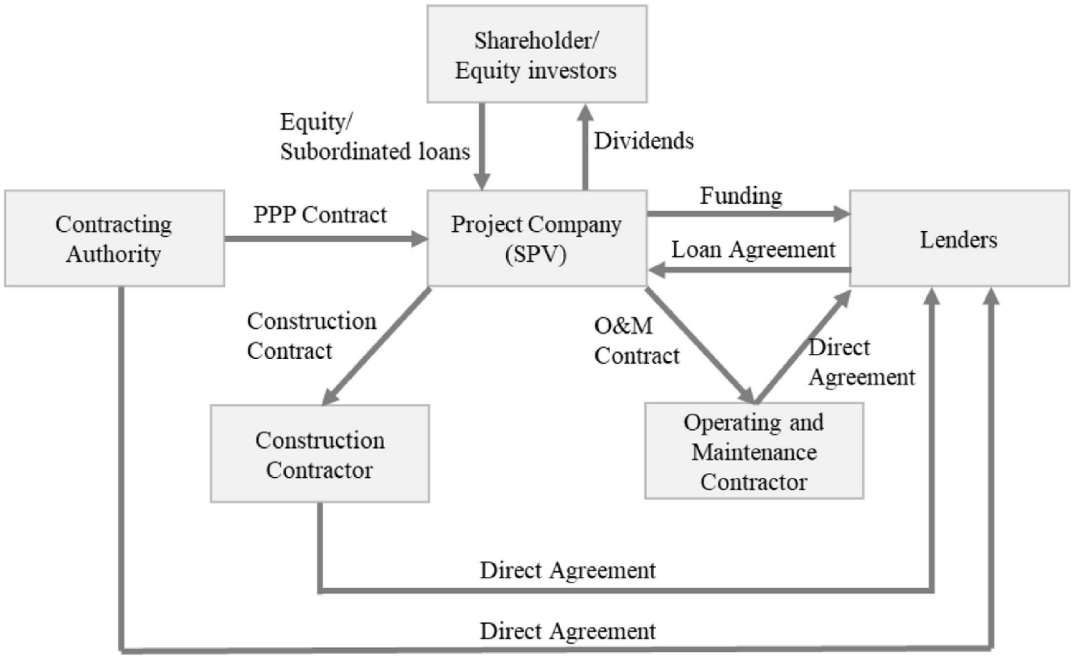

Figure 2.7: Governance of DBFM (Demirel et al., 2021)

The following private entities are typically involved in a DBFM project (Cartlidge, 2006; Grimsey & Lewis, 2004b):

- **Shareholders:** Provide risk-bearing equity and establish the SPC. Often large construction companies, infrastructure investors, or financial institutions like banks or pension funds.
- **Financiers:** Banks that provide loans and receive interest as return.
- **Insurance companies:** Contracted to mitigate specific financial and operational risks.
- **Subcontractors:**
  - Construction firms: Handle civil works and installations, often through a construction consortium.
  - Maintenance providers: Manage ongoing operations and facility services.
- **Advisors:**
  - Architects, lawyers, financial and technical advisors.
  - Employed by the SPC, financiers, or subcontractors, depending on the phase and risk structure.

These actors collaborate under a contractual framework aimed at minimising uncertainty and distributing risk in a clear and enforceable manner.

Project governance as described above is important however, successful project delivery also depends on strong public governance and enabling institutional arrangements put in place by public authorities. (Benítez-Ávila et al., 2018; Demirel et al., 2021).

2.4.6. Advantages of DBFM Contracts

This section highlights the potential theoretical benefits of DBFM contracts. It is important to note that these advantages are dependent on successful implementation and effective project management. In practice, various challenges can undermine these intended outcomes. Therefore, the following advantages should be seen as potential benefits, which may be realised if the contract is properly designed, managed, and executed.

Lifecycle Cost Efficiency

A core feature of DBFM contracts is their lifecycle approach, integrating design, construction, financing, and maintenance responsibilities under one contractor. This integration creates strong incentives for contractors to optimise total lifecycle costs and minimise long-term maintenance issues (J. Koppenjan et al., 2022). By considering maintenance and operational efficiency from the design phase onwards, DBFM contracts can reduce total project costs and risks of poor coordination between project phases.

Risk Allocation and Management

PPPs and DBFM contracts aim to allocate risks to the parties best able to manage them. This often means transferring substantial and sometimes all project risk to the private sector. By doing this the knowledge of the private sector can be utilised and thus increase efficiency (Bennett & Iossa, 2006).

Innovation Potential

In theory, private partners have strong incentives to innovate in design and construction to reduce costs and improve service quality. This includes the use of new materials, process optimisation, and more efficient asset management (Hoppe & Schmitz, 2013; Liu et al., 2023). The bundling of responsibilities over the entire lifecycle also supports the emergence of systemic innovation (Bennett & Iossa, 2006).

Value for Money

PPPs are promoted as delivering better Value for Money (VfM) through improved risk allocation, more efficient management, and private sector innovation. These synergies may reduce costs compared to traditional procurement, especially in the operational phase (Grimsey & Lewis, 2004b).

Budgetary Flexibility

Private financing enables infrastructure development without immediate strain on public budgets. Payments are typically made based on availability or performance, spreading the financial burden over the lifecycle of the asset and potentially enhancing long-term budget predictability (Wijnker et al., 2019; Yescombe, 2007).

2.4.7. Disadvantages of DBFM Contracts

Just as DBFM contracts offer potential benefits, they also come with risks and limitations which are identified in the following section. It is essential to recognise that these drawbacks do not always occur, but they represent recurring challenges identified in literature and practice.

High Transaction Costs

PPPs are associated with significant transaction costs, including legal, technical, and financial advisory fees, and complex contract negotiations. These costs can reach up to 10% of the total project cost (J. Koppenjan et al., 2022; Yescombe & Farquharson, 2018), making PPPs less suitable for small-scale projects unless standardisation or bundling is possible.

Higher Financing Costs

The cost of capital for PPP projects is generally higher than that of public provision, often by 200–300 basis points (Yescombe, 2007). This however, does fluctuate and does depend on the interest rates of the ECB for example. Furthermore, the higher cost of capital reflects the explicit pricing of risks normally hidden in public sector budgeting, as well as profit margins required by private financiers (Engel et al., 2010).

Innovation Constraints

While PPPs can incentivise innovation, private financiers may be risk-averse, limiting truly disruptive innovation (Liu et al., 2023). In cases where asset ownership reverts to the public sector, long-term innovation incentives may diminish, especially in build-operate-transfer arrangements (De Bettignies & Ross, 2004).

Rigidity and Inflexibility

The contractual nature of PPPs, especially in DBFM, creates rigidity due to the need to predefine many project aspects to mitigate opportunistic behaviour and incomplete contracting (Hart, 2003; Marques

& Berg, 2010). This can limit adaptability during project implementation, making changes costly and time-consuming (Engel et al., 2009).

Reduced Public Control and Design Influence

In DBFM contracts, the public sector has limited influence over detailed design and construction decisions. While this can improve efficiency, it also risks that the public client's preferences are not fully realised and that public value may be compromised (J. Koppenjan et al., 2022).

High Risk Profile

Because of the risk transfer and the larger integrated contracts, the risk for private contractors increases. This is because design, construction, and financing risks are all allocated to the private consortium. Furthermore, the price is determined for the entire project lifecycle of 20 to 30 years before the design is finalised, and there is little to no room for additional work orders. This further increases the risk of DBFM projects and contracts (J. Koppenjan et al., 2022).

2.5. Conclusion

This literature review has provided insights into the core elements and underlying principles of Design Build Finance Maintain (DBFM) contracts and their potential applicability to the specific context of infrastructure Replacement and Renovation projects in the Netherlands.

Firstly, the review established that R&R projects differ from new infrastructure projects due to higher technical uncertainties, operational disruptions, and the need to manage multiple stakeholders. Furthermore, the scarcity in capacity, budget constraints, and environmental regulation further make the R&R projects challenging.

Secondly,the procurement literature underlines that successful project delivery depends on strategic procurement decisions taken by the public client. Specifically, choices regarding the delivery system, reward system, contractor selection procedure and collaboration model impact tender outcomes and collaboration among project actors. Additionally, from the contractor's perspective, factors influencing the decision to engage in R&R tenders include tender costs, chance of winning, project risks and adequate rewards. Misalignment on these factors can significantly reduce private sector willingness to engage R&R projects.

Thirdly, DBFM contracts are recognised in literature as advantageous in managing lifecycle costs, incentivise innovation, optimising risk allocation, and aligning contractor incentives with public sector objectives through performance based payments. However, substantial critiques also emerge from the literature regarding DBFM, notably concerning high transaction costs, inflexibility, inappropriate risk allocation, and the high risk profile for contractors.

Finally, the review also identifies two complementary delivery methods that cut across contract forms. A programmatic approach can bundle related and repeatable R&R tasks to create economies of repetition, reduce transaction costs, and enable predictable scheduling and resource allocation. In parallel, industrialised construction applies standardisation, modularisation, and off site prefabrication to accelerate delivery, improve quality and safety, and support sustainability where assets are numerous and similar.

The resulting theoretical framework, derived from this literature analysis, links specific DBFM principles and the programmatic approach and industrialised construction to the identified R&R needs and associated risks. It offers a structured basis for assessing how DBFM principles might be practically adapted or selectively implemented in future R&R projects. This framework also forms the basis for the empirical analysis in this research.

2.5.1. Theoretical Framework

Table 2.1 summarises how DBFM elements and principles, together with a programmatic approach and industrialised construction, can contribute to addressing specific R&R challenges and opportunities, while also highlighting potential new risks introduced.

DBFM Element / Approach	Design Principle	Contribution to R&R (Challenges & Opportunities)	New Risks Introduced
Private Financing	• Financial discipline • Better risk management • Supplementary funding	• Budget discipline • Opportunity to accelerate urgent projects despite public budget limits	• Higher capital costs • Rigidity and inflexibility • Risk averse behaviour reduces innovation
Integrated Contracting (Design, Build, Maintain)	Lifecycle cost optimisation	• Cost efficient asset management • Opportunity for integrating sustainability	• Increased complexity • Higher transaction cost
Risk Transfer	Optimal risk allocation to the party best able to manage the risk	• Improved project delivery control • Leverage private sector expertise	• Inappropriate risk allocation • Reduced contractor interest
Performance Based Payments	• Incentive alignment • Performance incentives	• High infrastructure availability and quality • Innovation incentives for sustainability and reduced disruption	• Reduced direct control by public clients • Defensive behaviour to avoid penalties
Governance	Structured risk management and coordination	• Clear roles and responsibilities, improved risk management • Enhanced collaboration	• Increased governance complexity • High transaction costs
Long Term Collaboration	• Trust building • Learning • Innovation	• Continuous improvement • Implement innovations	• Reduced flexibility • Higher transaction cost
Programmatic Approach	• Strategic bundling and coordination • Learning across projects and predictable pipeline	• Economies of repetition and lower transaction costs • More predictable scheduling and resource allocation	• Reduced competition or SME access if bundles are too large • Higher client side governance and coordination load
Industrialised Construction	• Standardisation and modularisation • Off site prefabrication	• Faster delivery and reduced disruption • Cost efficiency and better quality and safety • Sustainability benefits and improved maintainability	• High upfront investment requirements • Design inflexibility when unique contexts dominate

Table 2.1: Theoretical Framework for DBFM Principles and Programmatic/Industrialised Approaches in Infrastructure R&R

3

Interview Results

This chapter reports the empirical study that explores how DBFM principles can improve R&R projects in the Netherlands. Semi structured interviews were conducted with public clients and with infrastructure contractors. The analysis is organised around the DBFM elements identified in Chapter 2 and the programmatic approach and industrialised construction are added because these are essential for the R&R challenge. Furthermore, the procurement components of delivery system, reward system, contractor selection procedures, and collaboration model are also included in the interviews. Although the focus of this research is on the design principles behind DBFM, the four procurement strategy components from Section 2.2.2 are included because they operationalise how such principles enter real projects. Furthermore in Chapter 6 these contract components are used to identify different collaboration models.

The aim of the interviews is to gain empirical insights into how principles from DBFM contracts can potentially improve replacement and renovation infrastructure projects in the Netherlands. These interviews will support the analysis of whether and how certain DBFM principles can be adapted for the specific challenges of R&R projects.

The interviews are also intended to identify how public and private actors currently approach collaboration and contract strategies, what their perceived barriers and opportunities are, and how recent developments such as two-phase contracts and portfolio contracts are being received in practice. The insights gained will contribute to answering the main and sub questions. Furthermore, the results are analysed to develop the decision making framework. In Appendix A the interview protocol can be found.

3.1. Methodology

To ensure consistency and relevance across interviews, the following steps will be taken:

1. **Interview Question Development:** Questions are drawn from the theoretical framework and aligned with the main and sub-research questions. Two slightly different interview guides are used: one for public clients (e.g., municipalities and provinces) and one for private parties (e.g., contractors).
2. **Interviewee Selection:** Respondents were purposively sampled to cover both public and private perspectives, with a deliberate emphasis on front end strategic decision making. We included participants with demonstrable renewal and DBFM experience and familiarity with two phase or portfolio procurement this includes procurement and contract advisers on the client side and tender, project, and contract managers on the contractor side.
    - *Public sector:* Individuals involved in infrastructure procurement and contract management of R&R within municipalities, provinces, or Rijkswaterstaat.
    - *Private sector:* Individuals working at infrastructure contractors with experience in DBFM contracts and R&R projects, involved with tender decisions and contract management.

3. **Approach Strategy:** Interviewees are approached via email, often through personal networks or referrals. The email briefly introduces the research and invites participation in a 60-minute interview.
4. **Interview Execution:** Interviews are conducted either in person or online (via MS Teams), recorded with permission, and guided by a semi-structured question set.
5. **Processing the Interviews:** Interviews are transcribed, anonymised, and coded using thematic analysis.
6. **Utilization of Findings:** Results from the interviews will be synthesised to answer the research question and sub-questions.

3.2. Interview Results

This section presents the findings derived from the conducted interviews. It provides a structured summary of the transcribed and coded responses, highlighting the most relevant insights shared by both public and private sector representatives. The aim is to capture practical experiences, challenges, and perspectives related to DBFM contract elements and their applicability for replacement and renovation projects.

Role Organisation	Role Interview	Interview Code	Date of Interview
Contractor	Director Infra	CO1	27-06-2025
Contractor	Director Infra	CO2	06-06-2025
Contractor	Manager PPS	CO3	03-06-2025
Contractor	Director	CO4	20-06-2025
Contractor	Commercial Director	CO5	20-06-2025
Contractor	Contract Manager	CO6	03-07-2025
Client	Advisor PPS	CL1	05-06-2025
Client	Advisor Market relations	CL2	01-07-2025
Client	Contract and Procurement Manager	CL3	16-06-2025
Client	Director	CL4	24-06-2025
Client	Advisor Procurement	CL5	26-06-2025
Client	Procurement Manager	CL6	18-06-2025
Client	Contract Manager	CL7	14-07-2025
Client	Contract Manager	CL8	17-07-2025

Table 3.1: Overview of Conducted Interviews

3.2.1. Characteristics and Challenges of R&R

Scope Uncertainty:
In new construction, the project starts with a “blank slate” or an empty area [CO1], resulting in relatively few uncertainties and better clarity regarding risks [CL1][CL8][CL3]. In contrast, R&R projects involve working within an existing structure or asset portfolio. The exact tasks that need to be undertaken often only become clear once the structure is dismantled [CO5][CL6][CL3][CL7]. There are numerous “unknown factors” and “behind-the-wall risks” (hidden surprises behind finishes or inside structures) that only surface during execution [CO2][CL4]. These high uncertainties are characteristic of R&R projects and must be considered when determining the appropriate collaboration model or contract form [CO3] [CO2] [CL1] [CL4].

Working in an Operational Environment:
R&R projects almost always take place while the asset remains in intensive use, often described as “keeping the shop open” [CO5][CL6][CO4]. This means that, unlike in new construction, the site cannot simply be cordoned off [CO5]. The societal pressure to keep infrastructure operational is high, as end users are primarily concerned with the availability of the road or structure. This results in increased complexity and requires coordination with many stakeholders and operators [CL6][CO4]. It also calls for a different approach to traffic disruption, where longer full closures are sometimes more efficient than numerous short disturbances during evenings or weekends [CO4].

Limited Design Freedom and Uniqueness:
New construction projects offer more design freedom. In contrast, R&R projects are characterised by limited flexibility, as they are constrained by existing dimensions and surroundings [CO4][CL4][CO6]. Each asset is often a “unique” or “one-of-a-kind” project, making it challenging to apply standardised solutions [CL4].

Changing Disciplinary Composition:
The civil component of R&R projects has often become smaller, while mechanical engineering, electrical systems, and automation take up a much larger part of the scope. This requires different technical profiles and expertise compared to traditional civil works [CO4] [CO2] [CO3]. This shift is particularly noticeable in tunnels and movable bridges. For example, in tunnels, the focus has shifted from purely civil engineering to “system engineering,” where the systems often dictate the civil components [CO2]. This can lead to “domino effects,” where small changes can have significant impacts on costs.

Scale and Volume of the Task:
The R&R task is enormous, with thousands of structures needing to be addressed in the coming years. This exceeds both market and government capacity [CL3] [CL6] [CL7] [CO1] [CO6]. The large volume necessitates a shift from custom-made solutions towards serial and modular approaches (“ready-to-wear” instead of “tailor-made”) [CL6]. The scale of the task is so vast that it is forcing a rethinking of outdated “project-by-project” methods, correcting systemic flaws in the sector [CL3].

3.2.2. Opportunities for R&R

One of the greatest opportunities in the R&R task lies in the potential for standardisation [CL4][CL6]. Instead of treating each project as a unique case, the focus can shift to identifying families of assets with similar challenges or solutions, enabling the introduction of technical standardisation [CL3][CL1][CL7]. This approach brings several benefits. By repeating the same tasks multiple times, project management plans, inspection protocols, and processes can be reused, resulting in significant efficiency gains [CO1][CO4]. Indirect costs related to preparation, design, and pricing can be substantially reduced through bundling and reusing of these processes [CL3][CO1]. Repetition also facilitates accelerated learning, as the same team working on similar projects develops a steeper learning curve and improves its performance over time [CO3][CL8]. Furthermore, standardisation enables modular and industrialised construction, which opens up possibilities for circularity and sustainability, for example by designing components to be easily disassembled and reused [CL5][CL4][CO4]. Finally, standardised designs make future maintenance more predictable and easier to perform [CL4][CL7]. In addition, this can improve the sustainability of the construction process [CL8].

3.2.3. Client Expectations of Market Parties

Openness, Transparency, and Trust:
Clients require contractors to be willing to share insights into their internal operations, particularly regarding cost drivers and the challenges they face. This openness is crucial for achieving successful collaboration based on the principle of "fair work for fair pay" [CL3][CL1][CL4]. Open communication and transparency between all parties are essential to address problems collectively and to leverage each other's knowledge. Issues must be openly discussed without assigning blame [CO2][CL4][CL3]. The market is expected to communicate honestly about costs and risks, stating the actual costs without fear of being "bargained down" by the client. Such clarity helps build mutual trust and facilitates constructive conversations [CL3]. Moreover, market parties must refrain from practices like price undercutting or other forms of opportunistic behaviour during tenders, as these actions erode trust [CL1].

Proactivity:
Market parties are expected to adopt a proactive attitude, taking initiative to highlight what is needed for the R&R task, including proposing solutions rather than waiting for direct requests [CL5][CL3]. Contractors should periodically pause to evaluate and improve processes instead of merely pushing ahead without reflection [CL6]. They can also challenge clients with smarter, more efficient, and improved solutions, potentially leading to significant cost optimisations through clever engineering. This may involve suggesting alternative materials if current options become prohibitively expensive [CL4][CL7][CL2]. Early involvement of the market is essential so that execution knowledge can be incorporated during the planning phase, ensuring feasible designs and better risk management [CL4][CL7][CO3]. Furthermore, the market should advise on the ideal characteristics of project portfolios and define the associated conditions [CL4].

Knowledge and expertise:
Clients rely on the knowledge and expertise of market parties. They require contractors' practical experience and cost expertise, which they may sometimes lack internally [CL7][CL3]. Market parties must present design choices or potential risks to the client in a timely manner [CL3][CL5]. They are also expected to deliver innovations while being honest about the feasibility and experimental nature of these innovations [CL7][CL3].

3.2.4. Contractor Needs from Clients

Predictability and Continuity in Assignments:
Predictable planning is crucial for contractors, as it allows them to allocate resources efficiently and invest in the necessary capacity or partnerships [CO2][CO5][CO3]. Timely awarding of contracts also contributes to this predictability [CO1][CO2]. A continuous workflow, or deal flow, is highly valuable because it enables companies to build stable teams, invest in expertise, and offer opportunities to young talent, rather than having teams disband after each project [CO2][CO3][CO6][CO4].

Early Involvement and Shared Knowledge:
Clients must involve contractors early in the planning phase to leverage execution knowledge, manage risks, and create feasible designs. Engineering firms sometimes lack this hands-on knowledge, which can lead to inefficiencies [CO5]. Open communication and transparency regarding cost structures, risks, and challenges are critical for mutual trust and effective problem-solving. Contractors should be able to communicate real costs without fear of being "bargained down"[CL1][CO6][CO4]. Clients must also recognise that, due to the high uncertainties in R&R projects, not all elements can be included in a fixed price upfront [CO2][CO5][CO6]. Moreover, clients should give contractors room to propose proactive solutions and innovative approaches, which can lead to optimisations through smart engineering [CO2][CO5].

Realistic Risk Allocation:
Risks should be allocated to the party best equipped to manage them [CO1][CL3][CO4][CL7]. Clients must be prepared to take on certain uncertain "behind-the-wall risks" themselves [CO1][CO5]. Unlimited liability for indirect damages is considered a red flag for contractors and is often uninsurable [CO1]. The inherent uncertainty of R&R projects calls for contracts that move away from fixed-scope, fixed-price agreements towards flexible pricing models [CO4][CO6].

Focus on Efficient Work Practices:
There should be less focus on non-essential tasks, such as unnecessary reporting or excessive procedural requirements, to free up capacity for the core objectives. As one contractor pointed out, the question should always be: "Will this make the ship sail faster?" [CO4][CO2]. Reducing administrative burdens and tender cost is also preferred [CO1][CO5][CO6]. Clients must also improve their decision-making processes, making them faster and less bureaucratic, so that good ideas from the market are not delayed or discarded [CO2][CO4][CO6].

Adjustment of Goals and Policies:
A shift in focus is needed from simply minimising traffic disruption to enabling efficient project execution. In some cases, longer planned closures may result in safer, cheaper, and more efficient work compared to multiple short-term interruptions [CO1][CO4].

Technical Knowledge and Leadership on the Client Side:
Clients need to strengthen their technical expertise and cost knowledge. This is essential for evaluating contractor proposals, assessing risks, and having a balanced and informed dialogue with the market [CO3][CO1][CO4]. Additionally, a cultural shift is required, with clients becoming more open, decisive, and proactive in their actions [CO3][CL7].

3.3. DBFM Elements

3.3.1. DBFM Element: Private Financing

Budget constraint:
At present, the Dutch government is struggling to utilise its available budgets for infrastructure projects, which means that private financing is not seen as a pressing issue or priority [CL5][CO1][CL7][CL4]. Furthermore, the government can borrow money at lower interest rates than the private market, reducing the financial incentive for private financing [CO3][CL5][CL2]. Market capacity is currently viewed as a greater bottleneck than the availability of funds [CO3][CO5][CL5]. Attitudinally, in the Dutch context, private financing has never been primarily used to keep projects off the government's balance sheet, unlike practices seen in other countries [CL4][CL1].

Inflexibility:
The involvement of banks and financiers tends to make contracts rigid and inflexible [CO5] [CL3][CL1] [CO3]. R&R projects, however, involve significant uncertainty about the exact scope and condition of the assets, requiring a flexible approach [CL5][CL3][CO2][CO1]. The inherent characteristics of R&R, such as the uncertainty of what will be encountered during dismantling and the challenges of working in an operational environment, are not well suited to the rigid structure of private financing [CO5][CL1][CO4][CO6].

High Transaction Costs:
DBFM contracts are known for their high tender and preparation costs, which can be an obstacle to efficient execution given the large scale of R&R tasks. These high costs are partly due to the detailed risk assessments required by financiers to secure the funding [CL1][CO3].

Advantages of Private Financing:
The involvement of private financiers introduces a "watchdog function" that helps ensure the contractor's performance, as financiers are motivated to protect their investments and guarantee repayment. This external oversight can instil a certain discipline in the project [CL1][CL4] and can also act as a safeguard against unnecessary additional work [CL1][CL4].
Private financing can also provide stable and long-term funding streams that are less dependent on annual government budgets [CL2].

Potential Future Need:
Although private financing is not currently a bottleneck, there are predictions that the challenges of aging infrastructure will increase exponentially after 2030. This could lead to a situation where private financing becomes a necessary instrument [CO1][CL3].

3.3.2. DBFM Element: Integrated Contracting and Life Cycle Cost Optimisation

Optimization of Life Cycle Costs (LCC):
Integrated contracts encourage contractors to select solutions that are cost-effective over the entire lifespan of the asset rather than focusing solely on the initial construction phase. This approach can result in more sustainable designs and lower maintenance costs in the long term. The concept of "maintainability" becomes an integral part of the design process [CO1][CO5][CL5][CL1][CO3].

Integration of Design, Build, and Maintenance:
Design-Build-Maintain (DBM) contracts are increasingly being applied to R&R projects, where the contractor is responsible not only for the renovation but also for maintenance for several years afterward. This responsibility encourages the contractor to consider maintainability during the design and construction phases. The typical lifespan of installations (often 10–15 years) makes this integration particularly relevant [CO1][CL2][CL3].

Optimization Throughout the Life Cycle:
By evaluating decisions across the full life cycle, contractors are motivated to choose more sustainable designs and apply materials that offer long-term cost-effectiveness. The incentive is to "deliver better quality that results in a longer lifespan" [CL4][CO3][CO4].

Improved Quality and Sustainability:
When LCC serves as the guiding principle, market parties are encouraged to opt for more robust and low-maintenance solutions, which improves both the quality and the durability of infrastructure assets [CL2].

Early Contractor Involvement:
Engaging contractors early, during what is called the "exploration phase," enables joint definition of the project scope and better risk allocation. This early collaboration allows all parties to assess trade-offs between initial investment costs (CAPEX) and future operational costs (OPEX) from the start [CO2][CO6].

Not Suitable for All Assets:
LCC optimisation through integrated contracts is less effective for assets with very long lifespans, such as concrete structures (50+ years), because maintenance costs arise much later in their lifecycle. It is more applicable to assets with shorter lifecycles, such as technical installations [CL3][CL2][CO3].

Risk of "Asset Depletion" and Knowledge Loss:
Without proper incentives, there is a risk that a contractor might "run down" assets toward the end of the contract period [CL5][CL3][CL1]. Because they are responsible for the maintenance for a period of time and cost is optimised based on the contract period, when the contract ends assets typically are just up to standard.

Budgetary Constraints:
The government's annual budget system ("cash-based accounting") can hinder LCC optimisation because long-term investments that are beneficial over the asset's lifespan may not fit within the yearly budget framework [CL1][CL5].

3.3.3. DBFM Element: Risk Transfer

Market Parties Avoiding Risks:
Due to the significant uncertainties inherent in R&R projects, market parties are no longer willing or able to take on all associated risks. This is partly because the market currently has plenty of alternative work and can afford to be more selective [CO1][CO5][CL3][CL2]. As one client remarked, "Market parties have enough work. So if we as clients do not set the right boundaries or risk allocation, we notice it immediately, because then no one wants to take on our projects" [CL3].

Joint Exploration of Risks:
To address this, market parties are involved at an early stage to collaboratively define the project scope and identify risks together with the client. Risks are then allocated to the party best equipped to manage them [CO1][CO2][CL5][CO4].

Client's Role in Accepting Risks:

The client must be willing to accept risks that the market cannot carry, especially low-probability, high-impact risks. This requires a culture of openness and transparency on both sides. Market parties must proactively bring potential bottlenecks and risks to the table for discussion [CL3][CO3][CO4][CL1][CL4].

A Stronger Steering Role for the Client:
To manage risks effectively, clients must strengthen their internal knowledge and competencies, particularly regarding execution and cost management. This allows them to act as an equal discussion partner and make well-considered decisions about risk allocation [CL3] [CL1] [CO1] [CO4]. As one client stated, “If we, as the client, take risks upon ourselves, we must also have the expertise in-house to properly assess these risks” [CL3].

Incentive for Efficiency and Innovation:
When risks are transferred, contractors are encouraged to innovate and work more efficiently to reduce costs and maximise profits [CO3][CL1][CL4][CO2].

Knowledge Loss:
The responsibility for deciding how R&R activities (maintenance, renovation, or replacement) are executed should remain primarily with the asset owner (the government) rather than the market. Social considerations regarding disruptions and quality must also stay with the government. Fully outsourcing these responsibilities could lead to the loss of technical expertise and operational knowledge on the client’s side, diminishing their role as asset manager [CL2][CL6][CL5][CL4]. As one interviewee stated, “By letting the market tender for solutions, we have lost much technical and asset knowledge. We were only able to assess what was being proposed. As a result, our role as asset manager has been eroded” [CL2].

3.3.4. DBFM Element: Performance Payments and Incentives

Encouraging Efficiency and Innovation:
Incentives can motivate contractors to work more intelligently and efficiently while encouraging the implementation of innovative solutions [CO5][CO1][CO6]. These incentives are designed to align the contractor’s interests with the broader objectives of the project.

Targeted Bonuses for Speed:
Although end users are primarily concerned with the availability and smooth flow of traffic, rather than the sheer speed of R&R projects, incentives can be structured around the robustness and reliability of project delivery. A bonus may be awarded if a project is completed ahead of schedule [CO1][CL3][CO6].

Bonuses for Sustainability and Life Cycle Cost (LCC) Optimisation:
Incentives can reward contractors for delivering higher quality, which translates into a longer lifespan for infrastructure assets. This approach promotes sustainability and reduces life cycle costs (LCC) [CL4][CL2].

Incentives for Future Projects:
Instead of rewarding additional work on the current project, incentives can be designed to grant contractors more work in future projects as a result of good performance [CO2][CL3][CL4]. This encourages contractors to adopt a long-term vision, knowing that efficient and high-quality performance will lead to continuity and future opportunities [CO2][CL3].

Perverse Incentives:
An excessive focus on speed may lead to safety risks and compromises in quality at the construction site [CL1][CL3][CO2]. Penalties are also often viewed as undesirable by clients because, while they may financially hurt the contractor, they offer no direct benefit to the client [CL2][CL3][CL8]. Such penalties tend to encourage “damage control” rather than proactive optimisation [CO6][CO3][CO2].

3.3.5. DBFM Element: Long-Term Collaboration

Learning Effects and Repetition:
Approaching R&R projects as a sequence of tasks within a single contract maximises learning effects [CL3]. The repetitive nature of R&R work, including the preparation phase, offers significant efficiency gains [CO1][CO6]. Since the underlying tasks and preparation processes are often similar, experience can be directly reused. This leads to more efficient design, pricing, and execution processes

[CL2][CL7][CO6].

Predictability and Continuity for Market Parties:
Long-term programmes provide contractors with predictable revenue and a stable income stream. This financial stability allows them to develop their organisations, keep teams consistently employed, and optimise the use of their equipment [CO1][CO2][CO4]. This predictability is highly valued by the market, as it reduces the uncertainty and fragmentation of workloads [CO5][CO6][CL8].

Improved Collaboration and Trust:
Long-term collaboration enables teams to get to know each other better and work together more effectively. A strong start is crucial because prolonged poor collaboration can lead to significant problems, described by one respondent as “horror” situations [CL8]. Open and transparent communication between client and contractor is critical for addressing uncertainties and managing risks effectively [CO1][CO5][CL2].

Dependency and Reduced Competition:
Excessive bundling of projects can result in contracts that are too large for smaller contractors (SMEs) to handle [CL6][CL7]. This may also lead to an over-reliance on one or a few large market parties. Furthermore, when demand outstrips supply, competition may decrease, which could drive up costs and reduce innovation [CL6][CL3][CL4][CL8].

3.3.6. DBFM Element: Governance

Governance structure:
Because of the absence of the private financing part there is no need of the complex governance structure with an SPC, EPC and MTC [CO4][CO5][CL3][CL8]. The structure is mostly a contractual framework and does not necessary mean better cooperation between the different actors [CO6]. It is also possible within this structure that parties involved in the SPC earn money while contractors involved in the EPC lose money which does not benefit cohesion [CL1][CO6]. Because of this cooperation is easier when same contractors are involved in SPC, EPC and MTC because incentives are aligned better [CO6]. The governance structure should encourage joint risk identification and decision making [CL5][CO4]. In a traditional DBFM with an SPC the client also has a controlling function and is not included in the SPC and decision making [CL1][CL3].
When talking about the governance structure the collaboration between client and contractor was often talked about. This is discussed in section about collaboration for R&R projects.

3.3.7. Price Mechanisms for R&R Projects

Challenges of Traditional Pricing Models for R&R:
One of the main challenges in applying traditional pricing mechanisms to R&R projects is the high level of uncertainty and the often undefined project scope. In many cases, the exact scope cannot be determined upfront, particularly when dealing with "behind-the-wall risks," such as unknown conditions of concrete behind tunnel linings [CL3]. This uncertainty makes it difficult for contractors to provide a fixed price that covers all risks, unless they add a substantial risk premium [CO1][CL2][CL5][CO2][CO5]. As a result, projects can become unnecessarily expensive, or contractors may submit unrealistically low bids, which later leads to conflicts and additional work claims [CL1][CL4].

Proposed Pricing Models and Approaches for R&R:
An alternative and increasingly preferred model is phased pricing or two-phase contracts. In this approach, part of the price, for example, the rates for personnel, equipment, and well-defined activities, is determined during the competitive tender phase [CL1][CL3]. For the uncertain parts of the project, the final price is agreed upon later, after a thorough "exploration phase" or study phase [CL1][CL6][CO4][CL8]. During this phase, the scope is jointly refined with the selected contractor, risks are assessed, and feasibility is optimised. This process requires a high level of transparency and openness from both parties [CO2][CO4][CO5].

Unit Prices:
For recurring and clearly defined tasks, unit prices can be agreed upon within framework agreements. This creates a "catalog of activities" that can evolve over time [CL3][CL1][CL7].

Open Book Mechanisms:
Open book pricing is becoming more relevant for R&R projects than for new construction. This model requires contractors to provide full transparency on their cost structure (open accounting) and often involves intensive monitoring by the client [CO1]. Some market parties, however, are hesitant about this approach [CO3][CO6]. A common concern is that open book mechanisms may reduce incentives for efficiency since profits are not directly linked to performance [CO1][CO5][CL7][CL8]. To counteract this, pain/gain share models can be implemented, where profit optimisation is shared between the client and contractor and thus incentivise efficient work and collaboration[CO1][CO3][CL8].

Risk of Over-Optimisation in Design:
Two-phase contracts can sometimes result in excessive time and money being spent on design and preparation phases, as parties attempt to eliminate all risks before agreeing on a fixed price [CL3][CL8]. This over-optimisation can delay project execution and reduce efficiency [CO4]. It is essential to find a balance between creating sufficient certainty and starting the works promptly [CL3][CO3][CO4]. Both [CL6] and [CL1] note that although more money may be invested during the initial phases of two-phase contracts, this investment pays off due to improved collaboration throughout the remainder of the project.

3.3.8. Selecting Contractors and Tender Criteria

Shift from Price to Value and Partnership:
The selection of contractors should focus less on awarding projects based solely on the lowest price and more on factors such as quality, expertise, innovation, and the efficient use of contractor capacity [CO5][CO1][CO6]. This approach encourages contractors to invest their energy in solving the challenges of the project rather than engaging in excessive competition [CL4][CO2][CO3][CO5]. Collaboration should be built on mutual trust and a shared commitment to addressing problems together, rather than being driven by contractual disputes [CL3][CL6][CO5].

Early Contractor Involvement:
Bringing contractors on board during the early preparation or exploration phase allows them to contribute their execution knowledge and expertise during design and scope definition. This early input helps to reduce failure costs and avoid surprises later in the process [CL6][CL1][CO2][CL8]. In some cases, this approach may require awarding a project before a fixed price has been fully agreed upon [CL2][CO5][CL7].

As one respondent stated: "In my opinion, we need to find a solution where market parties have more room to contribute during the early phase. This also requires Rijkswaterstaat to commit to less detailed

specifications in that phase and to accept that a price will not yet be available from us at that point" [CO2].

3.3.9. A New Approach to Collaboration in R&R Projects

Long-Term Collaboration and Programmatic Approach:
The scale of the R&R task calls for a different strategy than traditional object-by-object tendering. A programmatic approach, with serial tendering and framework agreements, creates longer-term partnerships that foster learning effects and repetition [CO1][CL3][CL2][CO2]. This provides the market with predictability and continuity of work, encouraging investments in staff development and training [CO1][CO5][CO6]. It also reduces transaction costs due to less frequent competitive tendering [CL1][CL3].

Knowledge Sharing and Early Market Involvement:
Clients and engineering firms often lack sufficient execution knowledge, which can result in designs or concepts that are difficult to implement. The market must proactively contribute ideas on constructibility, efficiency, and innovative solutions from an early stage [CO1][CO4][CL4][CL7]. Rijkswaterstaat, for example, needs to strengthen its in-house execution and cost expertise to act as an equal partner in discussions [CL2][CL4]. This early involvement helps to reduce distrust and encourages collaborative problem-solving [CL3][CL6].

A Culture of Openness and Trust:
A cultural shift toward greater openness and transparency is required from both sides [CL3][CL4][CO4]. This means openly discussing problems without immediately assigning blame to the other party [CL1] [CL5] [CL7]. The focus should move away from "settlements and contractual disputes" and instead center on delivering the project successfully [CO4][CO1]. Leadership and the creation of a safe team environment are crucial to enabling people to speak up about potential risks or challenges [CL6][CL8].

Focus on the Core Task:
The priority must be on safely and efficiently renewing assets, avoiding the "stacking of ambitions" or unnecessary "nice-to-haves" that make projects unnecessarily complex, delayed, and costly [CL3][CO5][CL8]. As noted by [CL5], redundant stakeholder management requirements should be "thrown in the trash" so that focus remains on the core objectives of the project.

As one respondent highlighted: "Ask each other the questions: What am I seeing incorrectly? What can you do from your expertise? And is there something simple that can eliminate the risk? These are the conversations we need to have together" [CO4].

3.3.10. Programmatic Approach

A programmatic approach, including the bundling of infrastructure assets, is regarded as crucial and necessary for efficiently and successfully addressing the extensive R&R tasks in the Netherlands. This strategy marks a shift from individual, project-specific custom solutions to a more serial, "assembly-line" method [CL2][CL3][CO5].

Bundling of Projects:
Bundling involves grouping multiple projects into a single, coherent portfolio. By doing so, standardised processes and resources can be efficiently utilised across multiple projects. This bundling approach significantly streamlines procurement processes, reducing the time and effort spent during tender phases, ultimately lowering transaction costs [CL4][CO1][CO5].

Efficiency Through Repetition:
Although infrastructure assets may differ individually, the nature of the tasks required, such as renovation works, often remains similar. This repetition allows teams to gain efficiency through continuous practice and incremental improvements, fostering a faster learning curve. Additionally, repeating similar tasks across projects reduces indirect costs related to preparation, design, and pricing [CO3][CO6][CL1][CL5][CL7].

Learning Effects:
Repeatedly conducting similar tasks enables teams to rapidly accumulate experience and improve performance. The gained expertise from earlier projects can be effectively applied to future works,

leading to higher-quality outputs and fewer mistakes [CL1][CL2][CL6][CO3].

3.3.11. Industrialisation

Standardisation and Modular Construction:
The R&R task requires a shift from tailor-made solutions to a more serial approach. This means standardising objects and components and adopting modular and factory-based construction methods [CL5][CO1][CL4]. Standardisation can be achieved through the use of uniform requirements or even by clients prescribing certain designs [CL5]. The goal is to create “Lego-like” components that are reusable [CL4] and simplify processes such as procurement, resulting in faster production rates and lower costs [CO5][CO6][CL7][CL8].

Predictability and Long-Term Planning:
For market parties, having a predictable schedule is crucial to deploying personnel and equipment efficiently [CO2][CO3][CO5]. A programmatic approach and long-term contracts provide “long-term revenue visibility” and help attract and retain talent [CO2].

3.3.12. Conclusion

Figure 3.1 provides an indicative overview of where respondents talked positively and more negatively about. The interview data was simplified in a positive or negative stance so the colours summarise tendencies rather than firm positions. Broadly, respondents expressed more reservations about private finance and one sided risk transfer, while views were more positive on integrated contracting with life cycle focus, long term collaboration, programmatic approaches, and industrialisation. Smaller differences also appear between clients and contractors, especially around the degree of acceptable risk transfer and industrialisation. In Chapter 4, each theme is broken down into underlying perspectives and checked against both the literature and the interview data.

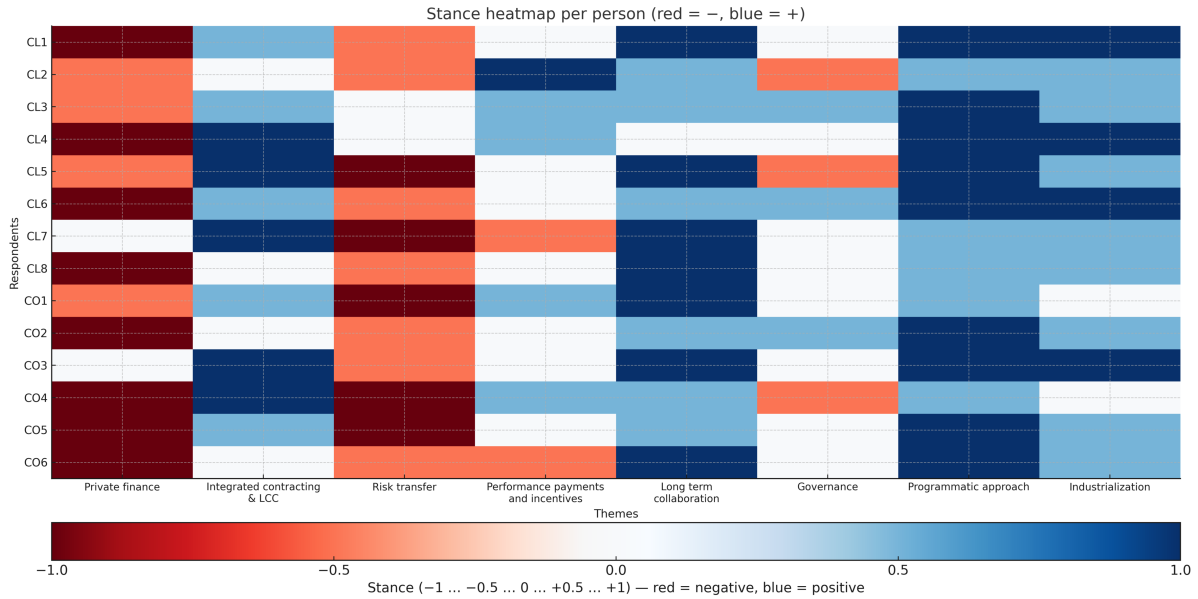

Figure 3.1: Heat map

4

Interview Analyses

This chapter presents an integrated analysis of the interview results in comparison with the findings from the literature review. The aim is to identify key similarities and differences between theoretical insights and practical experiences regarding the use of DBFM elements for replacement and renovation projects. The analysis serves as the foundation for the proposed framework and contract models discussed in the following chapters. The extended analyses can be found in Appendix C.

4.1. Interview analyses

4.1.1. Characteristics, Challenges, and Opportunities

Both literature and interviews note that Replacement and Renovation (R&R) projects face two major challenges: uncertainty about the condition of existing infrastructure and the need to work within operational environments. These factors make planning and execution complex. A key tension lies in limiting disruption of the operational system while still allowing efficient project execution. Furthermore, both client and contractor agree that the scale and volume of the R&R task also pose a significant challenge.

Interviews and literature agree on these core challenges, but some differences emerge. Interviews emphasise limited design flexibility due to existing structures, a growing need for technical expertise in system engineering, and the importance of making projects attractive to contractors given labour shortages. Clients appear less focused on the growing role of technical systems, even though contractors indicate that these systems are becoming the starting point of design, often dominating over traditional civil components. This shift requires new competencies within teams and organisations and increases project complexity.

There is broad agreement on the potential of standardisation and bundling to increase efficiency and lower costs. However, a contradiction arises: while R&R projects offer opportunities for industrialised and standardised construction, they must also fit into existing contexts. This limits design flexibility and makes standardisation more difficult, as each project must adapt to its surrounding environment.

One difference between literature and interviews concerns the upgrading of infrastructure networks. While the literature highlights this as an opportunity, adding public value and multi functionality, interviewees rarely mention it. This may be because such upgrades come with extra costs and complexity, and may conflict with goals of standardisation and efficient use of resources. Creating more public value through additional functionalities is not always feasible or desirable, especially given the scale and urgency of the R&R task.

4.1.2. Private Finance

While the literature identifies clear theoretical advantages of private financing, such as stable long-term funding, financial discipline, and risk transfer, interviews indicate that private finance is currently not considered necessary or desirable for R&R projects in the Dutch context. Public authorities have access to low-cost capital, and the main bottlenecks lie in market capacity, not funding availability.

There is consensus that the rigid structure of private financing, especially the requirements of financiers, conflicts with the high uncertainty in R&R projects. The unpredictable scope and complex operational environments make it difficult to set fixed budgets and timelines upfront. High transaction and financing costs further diminish the attractiveness of private finance.

Nonetheless, the literature and interviews acknowledge the added value of private financiers acting as external “watchdogs”, promoting performance and preventing scope creep. However, this benefit is mainly appreciated by public clients, while contractors often see it as a constraint. Incentives can play a role in trying to prevent scope creep and additional work orders making private finance not needed.

Some interviewees suggest that private finance could play a role in the future, especially if political decisions lead to reduced public funding. In such cases determining a stable scope and price are important. This can be achieved with a phased approach: the first phase, defining scope and cost, should be publicly funded, after which financiers can be involved with clearer conditions and reduced risks. This reduces risk premiums and makes private financing more viable.

4.1.3. Integrated Contracting and Life Cycle Cost Optimisation

Both the literature and interviews recognise that integrated contracts, such as Design-Build-Maintain (DBM), can stimulate contractors to optimise decisions based on life cycle costs (LCC). These incentives promote sustainable design, material choices, and maintainability. Interviews confirm that this is particularly relevant for assets with high operational expenses relative to capital investment, such as tunnels or movable bridges.

The opinion’s for the need for integrated contracts to ensure LCC are mixed. Unless the contractor is directly responsible for maintenance, there is doubt whether LCC will truly guide decision-making, though this can be partially addressed through incentives. For example awarding contracts based on total life cycle cost during tendering can strengthen LCC-based decision-making.

For simple, smaller-scale assets with minimal maintenance needs, including maintenance within the same contract may be unnecessary. In such cases, maintenance could be procured separately in bundled contracts.

One concern raised in interviews is the risk of asset depletion, contractors allowing assets to deteriorate toward the end of their maintenance obligation. This can be mitigated by setting clear contractual end-of-term performance requirements or even calculating residual value at contract expiry, offering financial bonuses for higher end-condition. This approach would encourage long-term thinking beyond the contractor’s own maintenance window.

Another important theme is the fragmentation between construction and maintenance teams. Often, different departments handle these phases, and maintenance is subordinate to realisation. More integrated collaboration is needed to improve outcomes and better utilise expertise from both sides. This is the case with contractors as well as with clients.

Public sector budgetary constraints also pose a barrier. The annual government budgeting system makes it difficult to fund long-term strategies, even if they offer LCC benefits.

4.1.4. Risk Transfer

Risk transfer is a central principle of DBFM contracts, but interviews show that its application in Replacement and Renovation projects requires a more nuanced and balanced approach. Both literature and practice agree that R&R projects carry significant uncertainties, such as unknown conditions and operational constraints, which market parties are increasingly unwilling to take on. This reluctance is reinforced by the current high market demand, which gives contractors more negotiating power and selectivity.

To ensure fair and effective risk allocation, early collaboration is crucial. By jointly identifying and exploring risks during early project phases, parties can decide who is best positioned to manage each risk. Risks that cannot reasonably be influenced or priced by contractors, especially ”behind the wall” risks should remain with the client. This collaborative approach prevents inflated risk premiums and ensures that projects remain feasible.

However, this requires public clients to have sufficient technical and contractual knowledge. Without it, they cannot engage meaningfully in these risk discussions or understand contractors' positions. Stronger internal capabilities allow the client to act as an equal partner and make deliberate, informed decisions about which risks to retain.

Although the literature notes that risk transfer can incentivise efficiency and innovation and interviewees agree on the need for contractor expertise for efficiency, clients are cautioned against transferring too much responsibility to contractors. When public clients outsource too much, they risk losing technical expertise, project oversight, and their role as long-term asset managers. This can lead to fragmentation, inconsistent practices across projects, and weakened strategic control.

4.1.5. Long-Term Collaboration

Both literature and interviews emphasise that long-term collaboration offers clear benefits for Replacement and Renovation projects. One of the most consistent findings is the value of repeated collaboration across projects, which enhances learning effects, builds trust, and increases efficiency. Long-term contracts such as DBFM with a maintenance component support this continuity. However, interviews suggest that even more effective forms of collaboration can arise from ongoing cooperation across multiple objects or projects such as framework agreements, with partly consistent teams on both the client and contractor side.

Long term collaboration also promotes predictability and continuity of project deal flow. This allows contractors to plan ahead, invest in people and innovation, use the available capacity efficiently. According to contractors, long-term planning and reliable project realisation timelines are even more important than the contract form itself. Predictable and stable deal flow also ensures stability across market cycles. Contractors note that current conditions favour the market, but economic tides can shift. Long-term cooperation reduces exposure to cyclical fluctuations and creates a more predictable business environment. However, this trust-based relationship depends on mutual respect and fair behaviour. Effective performance should be rewarded, while opportunistic actions must be discouraged. Both client and contractor rely on each other, and the relationship must be carefully managed.

That said, interviews also reveal a key concern: exclusivity. Long-term contracts and bundled project pipelines can limit opportunities for smaller or newer players to enter the market. This can have negative effects on price competition and innovation. Therefore, clients must ensure space for diverse market participation and sufficient capacity to maintain competitive pressure.

4.1.6. Performance Payments and Incentives

Performance-based incentives are widely seen as effective tools to promote alignment between client objectives and contractor behaviour. Literature and interviews agree that well-designed incentive structures can encourage contractors to work efficiently, adopt innovative methods, and improve sustainability and life cycle outcomes.

Interviews stress the importance of aligning goals between client and contractor. Incentives should reflect shared priorities such as quality, durability, and speed, while also safeguarding against unintended consequences. For example, bonuses for early delivery can be effective but should be capped or combined with conditions to maintain safety and long-term asset performance.

A promising strategy mentioned in interviews is to link incentives not only to individual project results but also to access to future work. Contractors that perform well could be rewarded with follow-up projects within a framework or programmatic structure. This encourages a long-term perspective, builds trust, and supports ongoing improvement across multiple assignments.

At the same time, interviews and literature highlight potential risks. Poorly designed incentives may lead to undesired behaviour, such as rushing execution or over-optimising for short-term outcomes. Penalties are generally seen as unhelpful because they focus on damage control instead of promoting proactive improvement. Positive incentives such as bonuses or future project rewards are seen as more constructive.

A concern raised in interviews is that strong performance payment mechanisms where you pay for a service instead of a product such as availability payments can lead to reduced client influence over

design decisions. This limits the client's ability to steer asset outcomes and can fragment approaches across projects. This is especially relevant in R&R where consistency and standardisation are important goals.

4.1.7. Price Mechanisms

DBFM contracts are fixed price contracts. While fixed price contracts offer cost certainty, both literature and interviews agree that they are often unsuitable for R&R due to the high levels of uncertainty involved. Hidden defects and scope changes are common in these projects, making fixed pricing unsuitable. Disputes, claims, and inefficiencies may arise when unforeseen issues cannot be handled within a rigid contract.

An alternative often discussed is the two-phase or staged pricing approach. In this model, risks and scope are explored in a first phase using more flexible price structures. After gaining sufficient clarity, a portion of the work can be converted into a fixed-price agreement. This method creates a balance between risk-sharing and cost control. This can be done with unit pricing, or schedule-of-rates mechanisms, is seen as a practical solution for many R&R contexts. The repetitive nature of tasks across similar objects makes it possible to define prices per unit of work. This provides flexibility and transparency while keeping cost control in place, especially when scopes need to be adjusted during execution.

A key challenge highlighted in interviews is the risk of over-optimisation during the design phase in two-phase contracts. When too much time and money are spent upfront to eliminate all risk before pricing, project momentum is lost. A balance must be struck between managing risk and ensuring timely project delivery. To prevent prolonged and inefficient design phases aimed at eliminating every possible risk, proper guidance and incentives are essential. This includes setting clear criteria during tendering or agreeing on a cost cap to trigger the start of execution. Clients also need to be prepared to take on certain risks themselves, so that contractors feel confident enough to proceed even in situations of partial uncertainty.

Cost-reimbursable contracts, such as cost-plus models, offer transparency and flexibility, which can be useful during initial exploration phases. However, they require strong discipline from both parties to maintain efficiency and cost awareness. These mechanisms are more collaborative by nature but may reduce the pressure on contractors to work efficiently.

4.1.8. Selecting Contractors and Tender Criteria

Both the literature and the interviews highlight the limitations of awarding contracts based solely on the lowest price. In the context of Replacement and Renovation projects, this approach often leads to reduced quality, lack of innovation, and increased risk of disputes. Instead, there is a clear shift toward value-based selection methods that consider quality, project-specific solutions, collaboration, and the contractor's track record.

Interviews indicate that many clients are now moving toward awarding contracts based on a contractor's performance in previous projects and their ability to act in a goal-oriented and collaborative manner. This shift not only improves project outcomes but also reduces transaction and tendering costs.

Early contractor involvement is another crucial element identified in both literature and interviews. When contractors are engaged early in the preparation or design phase, they can bring practical expertise to the table, helping to identify risks, improve buildability, and reduce failure costs. While this sometimes means awarding a project before a fixed price is fully determined, the benefits of better-informed decisions and smoother execution often outweigh this drawback.

Interviews further suggest that less competitive tendering processes could be acceptable, especially in today's market where contractors have a full pipeline of work. However, this assumes a fair and disciplined market where contractors do not exploit their position by charging excessive prices.

4.1.9. Governance & Collaboration Between Public Client and Contractor

Interviews indicate that the absence of private finance the governance structure with SPC, EPC and MTC is not strictly needed. Furthermore, the structure is based on contractual collaboration while both literature and interviews emphasise that successful collaboration in Replacement and Renovation projects depends on a cultural shift from transactional to more relational contracting. This involves

moving beyond rigid contract enforcement toward trust-based relationships, shared goals, and open dialogue. Literature underlines the importance of trust, transparency, and early contractor involvement as key enablers of effective cooperation. Interviews confirm this, highlighting that relational practices lead to more adaptive and productive partnerships. However clear responsibilities where both parties agree upon are essential this lowers the chances on conflicts and ambiguities. In a traditional DBFM with an SPC the client has a oversight role instead of an active roll in the SPC and decision making, while it is beneficial when decision are made jointly. This however, does not mean that the clear structure and decision making within the SPC has no benefits. It should only be based on more relational governance where also the client can influence decision making based on added value for example. This transform the DBFM governance towards a more alliance based model with joint decision making between client contractor and other partners and stakeholders.

One central theme is the need for early and open discussions about risks, dilemmas, and technical constraints. When public clients demonstrate technical and substantive expertise, it becomes easier for contractors to raise concerns without triggering defensive reactions. Clients who understand contractors' challenges can act as informed partners, which fosters mutual respect and trust. This knowledge also helps public organisations perform better in their asset management roles and reduces the tendency to rely solely on rigid contracts.

Furthermore, interviews highlight the importance of focusing on the core tasks of renovation and replacement projects. Prioritise value-adding activities directly linked to restoring the asset to its required performance/condition within time and budget. Strip out or streamline non core tasks such as excessive process management, duplicate reporting, 'nice-to-have' scope and unnecessary environment / communication packages. It is important to openly discuss what is needed for contractors to work efficiently and which activities are not needed. These dilemmas should be openly discussed and sometimes non core tasks should be skipped.

However, such relational approaches require time to build and must be supported by aligned incentives. Good behaviour and collaboration should be rewarded with follow-up work or preferred partnerships. At the same time, opportunistic actions or breaches of trust should have consequences. This encourages accountability while maintaining relational continuity.

A key insight from interviews is that relational contracting works well in theory but often breaks down when issues arise. In moments of conflict, the default reaction is often to fall back on the written contract. This points to the need for a deeper cultural transformation in public-private collaboration, where shared goals and mutual understanding are consistently prioritised over legal positioning.

4.1.10. Programmatic Approach

Both literature and interviews highlight the programmatic approach as a strategy for addressing the scale and repetitive nature of replacement and renovation projects. By bundling similar objects and managing them under a unified framework, clients can reduce transaction costs, improve efficiency, and enhance quality. Repetition of tasks across projects also allows contractors to develop specialised expertise, increased learning effect and efficiency. Another insight from the interviews is the importance of long-term planning and order predictability for contractors. The ability to anticipate future assignments enables better workforce and investment planning, making the market more resilient and efficient. However, contractors also expressed concerns about the uncertainty surrounding follow-up contracts. While it is reasonable for clients to impose performance requirements before awarding new work, the lack of clarity complicates planning and undermines some of the potential benefits of programmatic collaboration.

Interviews reveal that the current focus in practice lies primarily on bundling to reduce tendering costs and to benefit from learning effects. While this is already valuable, literature introduces a broader interpretation of programmatic management, including strategic resource allocation across projects. This dimension was largely absent from the interviews, suggesting a missed opportunity. A more strategic approach could involve identifying bottlenecks in personnel or materials and organising planning efforts to optimise the use of scarce resources across the entire program, rather than just within isolated projects or bundle of projects.

Finally, the interviews and literature both point out that large-scale bundling can pose challenges for

competition. If only a few large contractors are eligible to participate in bundled programmes, smaller players may be excluded, reducing innovation and market diversity. Clients must therefore ensure that entry points remain accessible to smaller parties, either by structuring bundles more inclusively or by creating space for smaller often more specialistic companies in joint ventures and consortia.

4.1.11. Industrialised and Standardised Construction

Both literature and interviews confirm that industrialised and standardised construction methods offer potential for addressing the growing scale of replacement and renovation tasks. Standardisation allows for repeated use of design and construction solutions, leading to lower preparation costs, shorter project durations, and more consistent quality. Prefabrication and modular approaches further support this by enabling more efficient and environmentally friendly construction processes.

However, the successful implementation of industrialisation requires more than technical adjustments. Contractors see the opportunities but are often reluctant to initiate industrialisation themselves. This is due to the significant upfront investments involved and an ingrained preference for bespoke, project-specific work. Therefore, clients must take a more active role in driving standardisation and industrialisation, while also engaging the market early to align interests and capabilities.

The current focus among public clients is mostly on bundling projects to lower transaction costs and benefit from repetition. Yet there is less attention to standardising designs or components, especially at the national level where many complex assets such as tunnels and movable bridges dominate the agenda. These complex projects are indeed more difficult to standardise. However, when it comes to simpler assets such as viaducts and small fixed bridges, standardisation is both more feasible and potentially more impactful. Local governments like provinces and municipalities are already exploring these opportunities.

To fully unlock the benefits of industrialised construction, greater alignment between different levels of government is essential. Shared standards and design templates would prevent fragmentation in requirements and promote economies of scale. This may require new forms of collaboration where higher-level authorities assist with procurement or set common guidelines, even if this means relinquishing some decision-making autonomy.

A key challenge remains the inherent contradiction in industrialisation: it limits the ability to optimize each project individually. There comes a tipping point where it is more efficient to stop customising and start standardising. Identifying this point, and understanding for which types and quantities of assets the investment in industrialisation is worthwhile, will be crucial. Maybe it is not feasible for the bigger tunnels but especially for relatively simple structures such as viaducts this offers great potential.

4.2. Conclusion

Table 4.1 consolidates the findings from this chapter. For each theme, it lists the underlying perspective identified in the interviews and indicates whether these are supported contractors, clients and the literature.

Theme	Conclusion	Literature	Contractor	Client
Characteristics and challenges	1. Uncertainty regarding the state of the infrastructure.	✓	✓	✓
	2. Working in an operational context increases complexity.	✓	✓	✓
	3. Scale and volume of R&R projects.	✓	✓	✓
	4. Increased complexity due to evolving technical scope	✗	✓	✗
Opportunities	5. Bundling of projects and standardisation/industrialisation.	✓	✓	✓
	6. Standardisation within an operational context can be difficult.	✗	✓	✗
	7. Upgrading infrastructure networks for increased value.	✓	✗	✗
Private Finance	8. Not necessary as supplementary funding; public funding is sufficient and cheaper.	✗	✓	✓
	9. Rigid structure not suited for uncertainty in scope and price of R&R.	✓	✓	✓
	10. Benefit of limiting scope creep and more discipline.	✓	✗	✓
Integrated contracts LCC	11. DBM contracts stimulate LCC optimisation for assets with high operational cost.	✓	✓	✓
	12. Concerns about asset depletion toward end of contract.	✗	✗	✓
	13. Fragmentation of operational and maintenance departments hinders LCC thinking.	✓	✗	✓
Risk transfer	14. R&R carries uncertainties and risks contractors are reluctant to take.	✓	✓	✓
	15. Phased approach with early contractor involvement is important.	✗	✓	✓
	16. Clients should retain certain risks (project unknowns).	✗	✗	✓
	17. Clients reluctant to transfer risk due to loss of influence and expertise.	✓	✓	✓
Long term collaboration	18. Repeated collaboration enhances learning and efficiency.	✗	✓	✗
	19. Contractors value long term predictability and stability of deal flow.	✗	✓	✓
	20. Enhances trust, communication and relationships.	✓	✓	✓
Performance payments & incentives	21. Well designed incentives align goals and increase efficiency and innovation.	✓	✓	✓
	22. Incentives awarding future works are promising.	✗	✓	✓
	23. Penalties are undesirable and may reduce quality and safety.	✗	✓	✓
Price Mechanisms	24. Fixed price not desirable for R&R due to uncertainty and risk.	✗	✓	✓
	25. Phased pricing allows definitive price to be set in the first phase.	✗	✓	✓
	26. Risk of over designing in the first phase.	✗	✓	✓
	27. Cost reimbursable contracts offer flexibility but also reduce pressure on contractors to work efficiently.	✗	✓	✓
Contractor Selection	28. Move towards more value based selection	✓	✓	✗
	29. Early contractor involvement	✓	✓	✓
Governance & Client–Contractor collaboration	30. More transparent and open communication about costs and risks.	✓	✓	✓
	31. Early contractor involvement to use expertise (even pre-competitively).	✗	✓	✗
	32. Importance of a knowledgeable client for good collaboration	✗	✓	✗
	33. Focus on the core task of R&R	✗	✓	✓
Programmatic Approach	34. Bundling similar objects reduces transaction cost and improves efficiency.	✓	✓	✓
	35. Programme management for strategic resource allocation.	✓	✗	✗
	36. Too large bundles may reduce competition and exclude smaller companies.	✓	✓	✓
Industrialised construction	39. Standardisation suits the repetitive nature of R&R.	✓	✓	✗
	40. Contractors are reluctant due to high initial investment and cultural resistance.	✓	✓	✗
	42. Modular and prefabrication can enhance maintainability and sustainability.	✓	✓	✓

Table 4.1: perspectives from literature, contractors, and clients.

5

Framework development

In this chapter, the results of empirical research are combined with the literature review to develop a decision making framework with guidelines for using DBFM principles for renovation and replacement projects. First, the insights from Table 4.1 are used to make recommendations related to the elements of DBFM and the programmatic approach and the industrialised construction presented in Section 5.1. These advices are then used to developed the initial decision making framework presented in Appendix D.1. then the feedback and insights from the expert evaluations are explained in section 5.2.1. Subsequently, the modified final version of the framework is presented in Section 5.3.

The aim of the decision making framework is to improve collaboration between client and contractor for R&R projects. The framework advices client about the use of DBFM contract principles based on certain context dimensions. In Chapter 6 three contract proposal based on the framework are given. Because there are a lot of different types of renovation and replacement projects there is not not one right answer or contract form that is applicable for all R&R projects. The frameworks tries to give general advices and the context when these advices more applicable and when they may be less applicable.

5.1. Initial Framework

The initial framework of displayed in 5.1, The extended explanation is given in this chapter.

Private Finance

1. Avoid private finance for R&R.

Given the high uncertainty of hidden conditions and the need for flexibility, private finance adds complexity and cost without notable benefits besides the disciplining role of contractors. This does not out way the downsides of higher transaction and financing cost and the rigid structure. Furthermore the main bottleneck of the construction industry is not finance but problems like capacity. The higher the uncertainty and complexity of a project is the more difficult it is to use private finance. This is because private finance make it so the contract becomes rigid and difficult to adapt. This can become a problem especially with complex projects that do not have a stable scope and price.

2. If private finance is used, first clarify scope and price.

If because for example of political reasons private finance is to be used the following is advised: Use it for the more simple projects with clear scope and price. Or use public funding for early investigation and scoping to de-risk the project before involving financiers. This limits risk premia, protects value for money, and avoids rigid finance-driven constraints during design. This can be done in a two-phase approach, where in the first phase the design and scope are clearly defined. After the first phase private finance can be introduced to finalise the realisation and maintenance part.

Integrated contracts and LCC

3. Prioritise life cycle costs and integrate maintenance expertise from the start.
Bring maintenance input into early decisions to optimise durability, availability, and total cost of ownership. Currently operations and maintenance departments are often fragmented and subordinate to the project realisation departments of clients and contractors. This can undermine the importance of the operational and maintenance phase of the project and thus reduce total LCC. Furthermore focussing on LCC can also improve sustainability of the construction industry, which is an important topic. This can be applied for all infrastructure projects but gets more important as the operational and maintenance cost relative to the construction cost increase.

4. Promote integrated delivery, especially where the operational cost is high.
Making a contractor responsible for a period of the operational and maintenance phase will force the contractor to think about this phase and optimise the design based on the realisation and maintenance phases. This promotes lowering operational cost and increased maintainability while also promoting more sustainable building practices. This is especially relevant for infrastructure with higher maintenance and operational cost such as locks and tunnels with technical systems. Because long maintenance contracts can reduce flexibility it is advised to not use contracts of 20 or 30 years but rather focus on maintenance contracts that have the same length as lifetime of the technical systems around 10-15 years.

Risk transfer

5. Use phased contracts when unknowns and risks are high.
Two-phase approaches allow a joint exploration phase to identify and reduce risks, followed by pricing once uncertainty is reduced. The risks that cannot be reduced such as ”behind the wall” risks should be retained by the client. This preserves momentum and guards against endless optimisation in phase 1 enabling smoother transition into the realisation phase.

6. Combine fixed price, unit rates, and cost-reimbursable elements.
Match pricing to risk: unit rates for repetitive work where quantity is unknown or flexible, reimbursable for exploration or genuinely uncertain tasks, such as ”behind the wall” risks and fixed price for well-defined packages where scope is clear. This mix balances flexibility with cost control. In practice this means that more complex project have less fixed prices and more unit rates & cost reimbursable prices while contractors should be able to give (more)fixed prices for simpler projects.

Both advise 5 and 6 are applicable especially for project with a lot of uncertainty. This also means that when projects become more complex and uncertainty increases phased contracts become more important and more time is needed for the first phase. Furthermore when uncertainty and risks are high less fixed price elements and more flexible pricing elements should be used. Contrary for less complex and less risky infrastructure a larger part of the price can be fixed price.

7. Invest in client-side technical expertise.
A knowledgeable client can participate in design decisions risk identification and deliberately retain inappropriate risks, which improves collaboration and reduces increased risk premiums. Furthermore technical expertise can strengthen the clients role as asset owner and manager being less reliant on market expertise.

Long-term collaboration

8. Use framework agreements to stimulate long-term collaboration.
Framework agreements stimulate long term collaboration across multiple projects. This enables lower tender costs, support learning, and create continuity across similar assets, which the market values. Framework agreements become more important and beneficial when there are a larger quantity of similar assets that have to be tendered. So for specific project with low similarities framework agreements are not or limited applicable. However, for structures such as viaducts where thousands have to be renewed coming decades it becomes more important and beneficial.

9. Provide a realistic plan and consistent deal flow.
Predictability lets contractors allocate scarce resources such as people and equipment efficiently and invest in expending necessary capacity. Furthermore it will create market stability across market cycles potentially lowering opportunistic behaviour. This also means that projects should not constantly be delayed even if maybe end of life is not totally reached. Because around 2030 the biggest peak of work

is expected projects should not be pushed back creating even bigger peak around 2030 instead the available capacity of market should already be used. However, prioritisation of which assets should be renewed first are important. A realistic planning also helps current maintenance teams that can optimise the remaining maintenance based on the date when infrastructure gets renewed.

Performance payments and incentives

10. Use incentives to align client and contractors goals

Positive, targeted bonuses for timely delivery, quality, and LCC outcomes drive behaviour can improve project outcome. Link bonuses to outcomes that matter for R&R. For example, promote efficient work and guarantee extra work flow with follow up projects. This can stimulate contractors to move to next project instead of trying to earn more on the same project with extra work orders. Bonuses are expected to work better than sanctions and help avoid defensive behaviour which can lower safety and quality standards while clients do not ”earn” anything from enforcing penalties. These incentives can limit extra work orders and stimulate efficient project completion.

Governance and client–contractor collaboration

11. Use contractor expertise early, even pre-competitive.

Make use of the markets expertise by involving them pre-competitively to shape how the project will be procured. For example to determine appropriated bundle content and size. Furthermore, early involvement improves buildability, risk realism, and bundle design that fits market capacity.

12. Promote open communication and transparency on costs and risks.

A culture and room to raise concerns, risks but also opportunities is important to stimulate collaboration. It is important for contractors to proactively communicate to clients what is needed to successfully and efficiently carry out work and projects. This can mean focus should be on the core task, reducing process management and administrative burdens but also reducing environment management or the focus on network availability.

Advise 11 and 12 can always be beneficial but become increasingly important when complexity and risks of projects increase.

13. Focus on the core task of R&R.

Projects can get increasingly complex when the focus broadens towards non core tasks of renewing infrastructure. This can be because of brocading the scope with ”nice to haves”, additional functionalities or excessive environmental or surroundings management. This can also be focusing to much on process management and reporting. Furthermore, focusing to much on network availability can hinder efficient use of capacity for contractors. It is important for public clients to only focus on adding functionalities or limiting disruption when benefits are high such as with the most important nodes of a network. This becomes increasingly important as frequency and repeatability become larger and when there is scarcity in market capacity. This is a trade-off clients must make; it should be discussed openly, including how the dilemmas affect project efficiency.

Programmatic approach

14. Bundle similar objects to reduce transaction costs and increase efficiency.

Repetition lowers preparation costs and speeds delivery it also increases the learning effect from project to project. Bundling becomes increasingly important when the quantity of similar objects is bigger. Furthermore the more the object are similar the more beneficial bundling becomes. Furthermore not all bundles or portfolio’s should become to big because this will reduce competition and exclude small and medium construction companies.

15. Promote consistent teams across projects for both client and contractor.

Stable teams accelerate learning curves and reduce coordination loss, improving outcomes over time. This is important in combination with advise 13 and also becomes increasingly important when quantity and similarity of objects increase.

16. Focus client attention more on strategic programme management.

Current focus of programme management is mainly focused on bundling objects, reducing tender cost and increasing the learning effect. Clients can benefit from looking beyond the bundling of individual projects and strategically govern resources, bottlenecks. This also means expanding to the whole supply chain to for example secure suppliers of certain resources. This also becomes increasingly

important when quantity of certain object is large and there is scarcity in resources or expertise for example.

Industrialised construction

17. Initiate and Co-develop standardisation and industrialisation with the market.
Currently clients start with bundling projects in portfolio's to standardise procedures and reduce tender cost. By standardising not only procedures but also components and objects the construction can be industrialised and efficiency can be increased. Furthermore industrialisation can reduce cost, increase quality and sustainability. This becomes increasingly beneficial when quantity and similarity of objects is large. So less beneficial or applicable for large complex assets such as locks and more applicable for smaller simpler objects such as viaducts and bridges.

18. Promote collaboration and standardisation between client organisations and government levels.
Standardisation and collaboration between different levels of government clients Rijkswaterstaat, provincial, municipal can increase economies of scale. Municipalities can use expertise of province or Rijkswaterstaat or even include their assets in a bundle procured by a province for example. Standardising across different level of governments also increases the repetitive nature of project which can promote industrialisation and efficiency. This is also mostly applicable for infrastructure that has a high quantity of projects such as viaducts and bridges.

Theme	Advice
Private Finance	1. Avoid using private finance for R&R as it is not suited for the uncertainty and risk associated with R&R. 2. If private finance is used, first clarify scope and price.
Integrated contracts & LCC	3. Give more priority to LCC and integrate maintenance expertise in projects from the start. 4. Promote the use of integrated contracts, especially for projects with high operational cost.
Risk transfer	5. Use phased contracts when risks and unknowns are high. 6. Use a mix of fixed price, unit prices and reimbursable prices to have flexibility and some certainty around price. 7. Clients should invest in technical expertise so they can join in risk identification and retain certain risks.
Long term collaboration	8. Stimulate long term collaboration, for example through framework agreements. 9. Make a realistic plan with a consistent deal flow so contractors can invest and act accordingly.
Performance payments & incentives	10. Use incentives to align client and contractor goals, for example to reward efficient work with follow up projects.
Governance & Client Contractor collaboration	11. Use contractor expertise early, even in a pre competitive stage. 12. Promote open communication and transparency around risks and opportunities. 13. Focus on task of renewing infrastructure and avoid to much ”nice to haves”.
Programmatic approach	14. Bundle projects so contractors can use their resources efficiently. 15. Promote consistent teams across projects for clients as well as contractors. 16. Focus client attention more on strategic programme management.
Industrialised construction	17. Initiate and co-develop standardisation and industrialisation with the market. 18. Promote standardisation and collaboration across public clients.

Table 5.1: Initial Framework

5.2. Decision making framework

This section translates the initial framework into a decision making framework (DMF). Because replacement and renovation projects vary in context and characteristics, several of the advices listed in Table 5.1 are context dependent. In general the advices apply to most R&R projects, yet some become especially relevant in particular contexts while others lose significance. For example advice 17 becomes more significant when repeatability and quantity of an specific asset is high, while on the other hand when complexity is high this becomes less applicable. The decision making framework helps public clients identify which advices are especially relevant by a given project context. These recommendations can be combined to help create a suitable contract or collaboration model for procurement. in Chapter 6 three possible contract proposals are explained. In Section 5.2.1 the validation of the initial DMF is explained, in Section 5.3 the Final DMF is presented.

5.2.1. Validation of the Decision-Making Framework

The initial DMF can be found in Appendix D. The framework works as an advice × context matrix, the columns capture five context dimensions that influence the applicability and value of the advice. This framework can help public clients go from context → advice → contract design. An extensive explanation of the DMF is given in Section 5.3.

Purpose and design of the validation session

The original decision-making framework was validated by experts. The purpose of the validation is to assess whether the decision making framework, its five context dimensions, the advice and the translation into contract choices, is clear, complete, and workable for the Dutch renovation & replacement (R&R) context. Concretely, the validation examined:

- **Context dimensions:** clarity and usefulness of the five dimensions and whether they capture the main drivers in Dutch R&R.
- **Advice–context mapping:** correctness and sufficiency of the advice × context matrix, including the meaning of markers and whether any advices are missing or redundant.
- **Translation to contract design:** applicability of the output to the three contract proposals of Chapter 6 in Dutch governance and market settings.
- **Usability and completeness:** ease of use, completeness, and usefulness of the framework.

Four semi structured 1:1 interviews were conducted with experts from public clients and contractors. The validation protocol can be found in Appendix E Participants were selected to ensure:

- **Role diversity:** coverage of the two perspectives in Dutch R&R delivery (client, contractor).
- **Relevant experience:** proven track record in R&R projects and in programme delivery and bundling.
- **Procurement expertise:** practical familiarity with DBFM elements and adjacent procurement choices.
- **Independence:** interviewees were not previously involved in this study.

Results expert evaluations

In the following section, feedback received during the expert evaluations on different parts of the initial framework is discussed: (1) advices in the initial framework, (2) context dimensions and the decision-making framework (DMF), and (3) contract proposals. Furthermore, the applicability of the framework is discussed implicitly within each subsection.

(1) Advices in the initial framework

- **Overall recognition and importance.** All respondents noted that the recommendations in the framework were recognisable and important for practice.
- **Clarify "nice-to-haves".** E1 and E3 asked to clarify what is meant by "nice-to-haves" and noted that some explanations become clearer with additional context. They agreed it is essential to *first* define the primary project goal (e.g., pure renewal, traffic flow, accessibility), as this influences decision-making and the relative importance of recommendations.

- **Make sustainability explicit.** E4 observed that sustainability is underexposed and should be made explicit in the life-cycle approach and in industrialisation pathways.
- **Relative emphasis within the set.** E2 indicated that some recommendations may be more important than others across many contexts, e.g., *A9* (realistic planning with a consistent deal flow) and, relatedly, *A18* (standardisation and collaboration across public entities) because it helps create deal flow.
- **Consistent teams.** E3 emphasised that consistent teams across projects are extremely important for almost all projects within a bundle.
- **Promote collaboration across public clients.** E4 noted that collaboration across public clients is also important to use each others expertise and knowledge. Not every municipality can be an expert on all infrastructure objects so emphasised that consistent teams across projects are extremely important for almost all projects within a bundle.

(2) Context dimensions and DMF

- **Define terms explicitly.** E2 noted that context dimensions can be interpreted broadly, which can be useful, but the definition used must be explicit. For example, *Complexity* can be technical, operational/network, or stakeholder/permit-related.
- **Treat scarcity as multi-dimensional.** E1 and E2 noted that scarce market capacity spans budget, materials/plant, and people/skills.
- **Context can be (partly) chosen.** E3 stated that some dimensions can be influenced by scoping: repeatability can be created by how scope is defined and assets are bundled; scope choices can also raise or lower complexity.
- **Policy ambitions drive prioritisation.** E4 stated that policy ambitions (e.g., cost, accessibility, sustainability) determine which recommendations should be prioritised. Because goals often conflict, this also influences contract decision-making.

Context markers

- **Adjust markers for key recommendations.**
  - E2: give *A3* (priority to total life-cycle cost) a "✓" under *Complexity*, as LCC grows in importance when assets and systems are complex.
  - E1: give *A3* and *A6* a "✓" under *Scarcity*, since LCC and integrated contracts can promote efficient use of scarce resources.
- **Always-on recommendations.** It was discussed that some recommendations apply in almost every situation (e.g., *A9*, *A11*, *A15*); note this explicitly.

Contract proposals

- **Nuance O&M importance (Proposal 2).** E3 warned that labelling O&M importance as "low to medium" can be risky without nuance; even "simple" assets can become expensive if O&M is under-specified or poorly executed.
- **Tie maintenance term to life cycles.** The 10–15 year maintenance term should always be tied to specific component/system life cycles, not arbitrary contract lengths.
- **Align incentives (Proposal 3).** E4 noted that incentives should align client and contractor goals. In an alliance/open-book setting, the goals are not automatically aligned ("as much value for the money" vs. "as much money for the value"); explicit alignment mechanisms (e.g., pain/gain share) are required.
- **Future-work incentives must be credible.** E1 noted that If incentives include future work, guarantees must be credible. This can be done by broadening the scope. When guarantees are not specified where work has to be carried out it can also be fulfilled at another location or even by another cooperating client.

5.3. Final decision making framework

After implementing the relevant feedback from the validation session the final framework is presented in Table 5.2. A Dutch version of the framework and explanation are given in Appendix F.

How the decision making framework works

The framework presents an *advice* $\times$ *context* matrix. The columns capture conditions that influence the applicability of the advices these are: uncertainty, complexity, repeatability, O&M importance, and scarce market capacity explained in next paragraph. Each cell records the directional association between a context and an advice: "✓" means the advice becomes more valuable as that context increases, "✗" signals a condition where the advice may be counterproductive or needs extra attention, "▲" indicates a mixed effect which can be positive and negative, and a blank cell means that the advice is applicable but not extra valuable in the specific context. During the expert evaluation it was noted that some advices where always applicable regardless of the context, these are noted with a "*" next to the advice. To use the matrix, decision makers should have made strategic decisions about the project goals because this influences the context dimensions. After these strategic decisions the project should be profiled using the context dimensions this is done for three examples in Section 5.4; next, priorities the advices marked "✓" for those conditions and note any "✗" and "▲"cells that must be addressed. Finally, translate the selected advices into a contract or collaboration form. This last step is done in Chapter 6 An extended explanation of the decision making framework including the context dimensions rubric and relation between the context dimensions and advices(✓, ✗, ▲) is explained in Appendix C.

How to apply the framework

1. **Clarify goals.** Confirm strategic project goals and decide on how to bundle certain objects.
2. **Profile the context.** Score the project on the five dimensions (uncertainty, complexity, repeatability, O&M importance, scarce market capacity) using the rubric in Appendix C.
3. **Select and prioritise advice.** Identify advice items marked ✓ for the scored conditions as the baseline; flag items marked ✗ as risks or constraints; note ▲ items for case specific tailoring.
4. **Translate into contract choices.** Map the resulting advice set to a contract or collaboration model based on the DBFM elements and delivery system, reward structure, selection procedure, and collaboration model.

Intended users and use cases

The decision making framework is primarily intended for public clients responsible for procurement of replacement and renovation work, such as Rijkswaterstaat, provinces, municipalities and water authorities. It supports these organisations in profiling a project or bundle along the five context dimensions from Chapter 5 and in translating the activated advice into choices of a contract or collaboration model. As secondary users, contractors and engineering consultants can apply the same logic to test if a project is a fit, structure early dialogue, and make bid or no bid decisions. In all cases the framework is meant for the strategic front end of projects and programmes, where context must be made explicit and where contract design is still open. The DMF provides the context $\rightarrow$ advice $\rightarrow$ design traceability used in Chapter 6 to help build fit for purpose contracts.

5.3.1. Context dimensions

This section briefly defines the context dimensions used in the decision making framework. The aim is to clarify what each dimension captures and which kind of evidence informs its assessment. A detailed scoring rubric and practical guidance for profiling projects are provided in Appendix C.

Uncertainty How much we do not know about scope, conditions and requirements. Examples of evidence: Quality of inspections and condition data, the number of provisional items, and how stable external requirements and design inputs are.

Complexity Covers both technical and institutional aspects. On the technical side: number of disciplines and interfaces. Furthermore, larger projects are often more complex. On the institutional side:

how many stakeholders have decision rights, shared access constraints, and the amount of regulatory coordination needed. Furthermore the requirements regarding sustainability and network availability influence the complexity.

Repeatability How similar the assets and work steps are, and how much we can reuse methods, details and components. This also include the quantity of similar assets. Evidence includes the size of asset families, presence of standard details, and the potential for series production and learning.

Operations and maintenance importance How much O&M matters in life cycle cost and how critical availability is during use. Indicators are availability requirements and access windows, maintenance frequency and intensity, energy use, and the need for maintainability by design.

Scarce market capacity How available the market is in the delivery window: skilled people, key equipment, and critical suppliers but also how much budget is available. Look at the number of credible bidders, lead times, pressure on specialist crews or equipment, and supplier bottlenecks.

Advice	Uncertainty	Complexity	Repeatability	O&M importance	Scarce market capacity
1. Avoid using private finance for R&R.	✓	✓			
2. If private finance is used, first clarify scope and price.	✓	✓			
3. Give more priority to total LCC from project start.*				✓	✓
4. Make use of integrated contracts.		▲	✗	✓	
5. Use phased contracts to jointly reduce risks and unknowns.	✓	✓			
6. Use a mix of fixed price, unit prices and reimbursable prices to balance flexibility and price certainty.	✓	✓	▲		
7. Invest in client side technical expertise.*	✓	✓		✓	
8. Stimulate long term collaboration.			✓		✓
9. Make a realistic plan with a consistent deal flow.*					✓
10. Use incentives to align client and contractor goals.*					
11. Use contractor expertise early, even in a pre competitive stage.*	✓	✓	✓		✓
12. Promote open communication and transparency around risks and opportunities.	✓	✓		✓	
13. Focus on task of renewing infrastructure.		▲	✓		✓
14. Bundle projects so contractors can use their resources efficiently.		✗	✓		✓
15. Promote consistent teams across projects for clients as well as contractors.*		✓			✓
16. Focus client attention more on strategic programme management.			✓		✓
17. Initiate and co-develop standardisation & industrialisation with the market.		✗	✓		✓
18. Promote standardisation and collaboration across public clients.		✗	✓		✓

Legend: ✓= positive ▲= context dependent ✗= negative ⋆ = always applicable.

Table 5.2: Final Decision making framework

5.4. Applying the decision making framework

This section demonstrates how the decision making framework is used. We first profile three context archetypes (the *input* to the framework) based on the context dimensions uncertainty, complexity, repeatability, O&M importance and market scarcity. We then list, for each archetype, the advices that are activated (the *output* of the framework). In Chapter 6, these outputs are translated into full contract models.

5.4.1. Context archetypes (framework input)

The project archetypes are possible project scenarios that can be profiled using the context dimensions and the DMF. These archetypes intentionally exaggerate the ends of each scale to make the decision logic transparent. Real projects can often fall between profiles. Furthermore, scope choices and project goals can also shift the context, for example by creating repeatability or by reducing complexity. Additional to the description of the archetypes some fitting examples of projects are given that could fall under the three archetypes.

Context A: High uncertainty & high complexity, low–medium repeatability
Description: R&R project of assets with dense technical integration and limited scoping certainty. Assets are related but not uniform, which constraints technical standardisation. Because they are embedded in an operational system, operations and maintenance costs are relatively high. This context typically covers larger, complex projects such as tunnels, locks, and large movable bridges.

Fitting examples:

- Renovation of a road tunnel including replacement of ventilation and control and safety systems under tight closure windows.
- Replacement or life extension of three large movable bridges with technical and operating systems.
- An integrated corridor intervention with multiple interdependent structures and traffic phasing that interact.

Profile: Uncertainty = High; Complexity = High; Repeatability = Low–Medium; O&M importance = Medium–High; Scarce market capacity = Medium.

Context B: High repeatability, low–medium complexity
Description: Families of identical or highly similar assets with stable scopes and low complexity. High repeatability enables standardised solutions and industrialised methods, which accelerates delivery with limited capacity. This context typically covers series of viaducts or smaller concrete bridges that can be tackled in the same way.

Fitting examples:

- A programme to replace large quantity of standard viaducts with comparable spans and details.
- A series of concrete renovations on small fixed bridges, using reusable details and prefabricated components.
- Large-scale replacement of systems that can be standardised, such as lighting or traffic management installations.

Profile: Uncertainty = Low–Medium; Complexity = Low; Repeatability = High; O&M importance = Low–Medium; Scarce market capacity = Medium–High.

Context C: Scarce capacity with a binding budget envelope, high uncertainty
Description. A setting where capacity is the dominant constraint and a fixed annual budget must be maximised. The portfolio is similar enough to organise sequencing and learning, yet diverse enough to require ongoing optimisation of prioritisation and interventions. Uncertainty remains relatively high and the standardisation of interventions is limited.

Fitting examples:

- A municipal multi-year programme for replacement of inner-city bridges with varying asset conditions and limited contractor capacity.
- A renovation programme for quay walls where the locations and intervention differ and the annual budget steers the work mix and planning.

Profile: Uncertainty = medium; Complexity = Medium; Repeatability = Medium; O&M importance = Medium; Scarce market capacity = High.

5.4.2. Output framework

This section summarises the *output* of the decision making framework for three archetypal context profiles. Using the rubric in Appendix C, each profile is scored on the five dimensions; the advice $\times$ context matrix then activates the relevant advices. The lists below are not strict instructions; they highlight priorities and flag cautions to later guide contract design choices. Items marked with "*" are baseline practices that generally apply. Chapter 6 translates these outputs into concrete contract configurations, keeping a clear trace from *context* $\rightarrow$ *advice* $\rightarrow$ *design*.

Context A Input: Uncertainty = *High*; Complexity = *High*; Repeatability = *Low–Medium*; O&M importance = *Medium–High*; Scarce market capacity = *Medium*.
Output (advices activated): **1, 3, 4, 5, 6, 7, 10, 11, 12, 15**.

Context B Input: Uncertainty = *Low–Medium*; Complexity = *Low*; Repeatability = *High*; O&M importance = *Low–Medium*; Scarce market capacity = *Medium–High*.
Output (advices activated): **1, 6, 8, 9, 10, 11, 13, 14, 16, 17, 18**.

Context C Input: Uncertainty = *High*; Complexity = *Medium*; Repeatability = *Medium*; O&M importance = *Medium*; Scarce market capacity = *High*.
Output (advices activated): **1, 3, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15**.

In Figure 5.1 the three different archetypes are plotted using the five context dimensions. It shows where the context overlap and where they differ. They are further used in Chapter 6 where they are linked to a specific contract proposal.

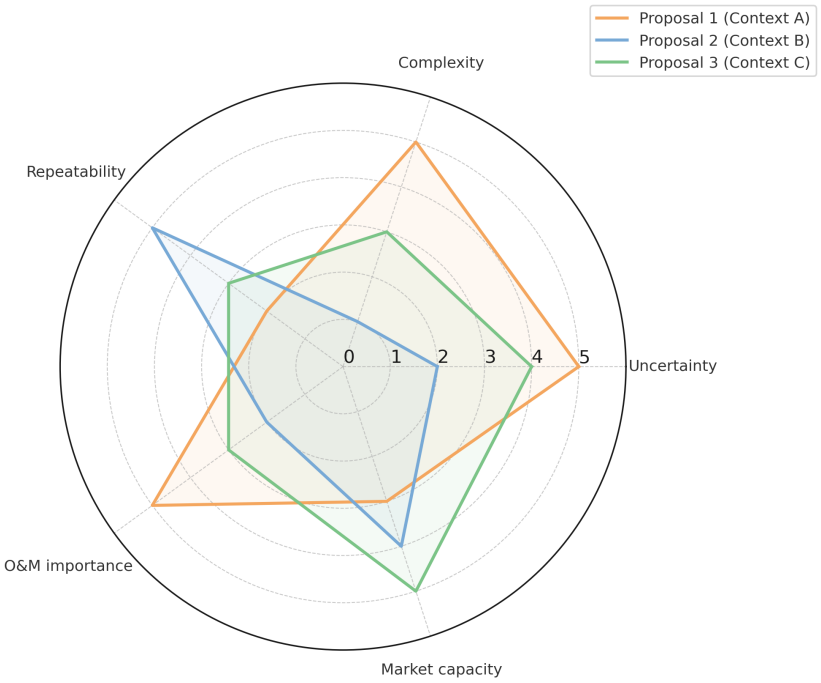

Figure 5.1: Positioning of the three proposals across the five context dimensions.

6

New Contract Types

This chapter translates the outputs of Section 5.4 into three concrete contract proposals. In Chapter 5 the project contexts were profiled along five dimensions and, per context, a set of advices was activated. First, a context is characterised, then the relevant advices follow from that profile, and finally in this chapter these advices are translated into three illustrative contract configurations that combine DBFM elements: Private finance, Integrated contracts, Risk transfer, Performance payments, Governance and Long term collaboration. Furthermore the contract components from (Eriksson, 2017): delivery system, reward structure, selection procedure and collaboration model are added.

These configurations are not meant as final or universally optimal solutions. They show how existing mechanisms can be adapted or recombined to fit specific R&R contexts identified in Chapter 5. Other variants and combinations of the proposals are possible in practice.

The structure of the chapter follows the mapping from Chapter 5. The context with high uncertainty and complexity, limited repeatability and substantial operations and maintenance importance feeds into Proposal 1, a two phase integrated DBM with a system life maintenance horizon. The context with lower uncertainty and lower complexity and high repeatability feeds into Proposal 2, a framework agreement with standardised solutions. The context where a fixed budget must be converted into maximum output across a bundle feeds into Proposal 3, a budget driven open book portfolio.

Reading guide We map the Chapter 5 contexts directly to the proposals:

- *Context A* $\rightarrow$ **Proposal 1**: two-phase integrated DBM with a system-life maintenance horizon.
- *Context B* $\rightarrow$ **Proposal 2**: framework agreement with standardised solutions.
- *Context C* $\rightarrow$ **Proposal 3**: budget driven open-book portfolio.

Each proposal begins with a short recap of the underlying context from Chapter 5, then states the purpose of the model, lists the applicable DBFM elements and sets out the contract design choices.

visual context profiles

The visual context profiles for all the proposals are also given. In Figure 5.1 you all three context profiles are combined showing where they overlap and differ. This graph can also be used to plot a different context and compared with the three context profiles shown in this research. This can give an indication what type of proposal best suits the specific context. For example plotting a project context which falls in between proposal 1 and 2 (context A and B) can mean the contract should incorporate both elements from proposal 1 and 2.

6.1. Proposal 1: Two-phase integrated DBM contract

Context recap. High uncertainty and high complexity due to hidden conditions and access constraints on large assets such as tunnels and locks, or on a corridor with multiple objects. Repeatability is limited to moderate and technical standardisation is low. Operations and maintenance importance is substantial because of the technical systems and availability of network. Market capacity is moderately tight, which makes continuity of teams and predictable planning valuable.

Implements advices: 1, 3, 4, 5, 6, 7, 10, 11, 12, 15.

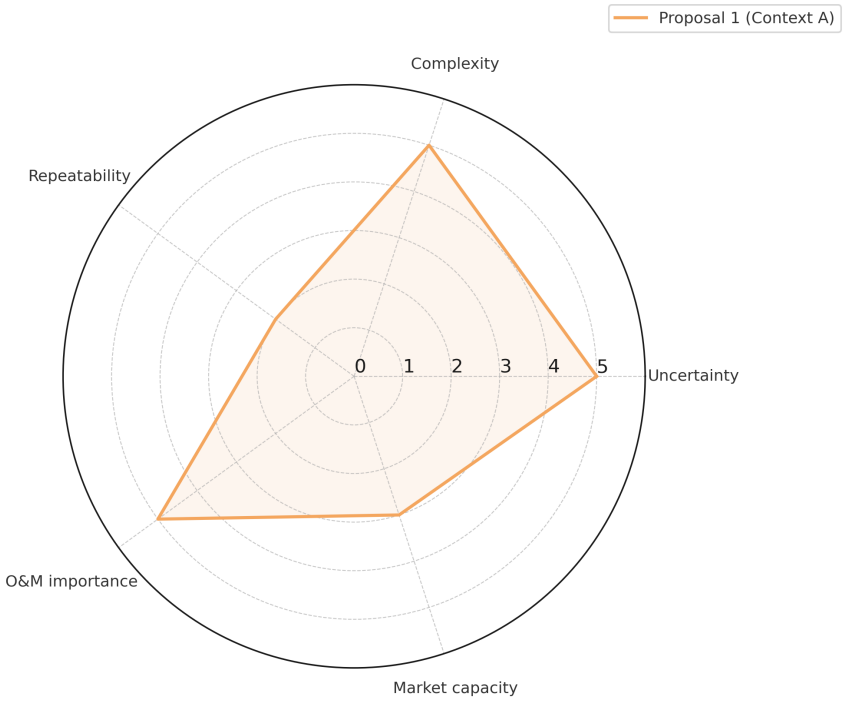

Figure 6.1: Context profile for Proposal 1 (Context A).

Purpose of this model. The model aims to make complex and uncertain renewal projects manageable by using a phased approach and keeping a stable team across a projects. Phase 1 includes asset condition assessments, risk assessment and design, so that the most material unknowns and risks are explored before the realisation phase. This phase uses more flexible pricing because of the large number of unknowns. After scope certainty increases a final price is agreed at the end of phase 1. A flexible or reimbursable component can remain for ”behind the wall” unknowns. Phase 2 has final design, construction, and 10–15 years maintenance based on the technical lifetime of the systems. Selective risk transfer puts foreseeable and manageable risks with the contractor and keeps truly unpredictable behind the wall risks with the client. A focused maintain period of about ten to fifteen years is included, because of the importance of the operational and maintenance phase. This incentivise the contractor to improve life cycle cost and reduce disturbance. This approach tries to manage uncertain and complex infrastructure renewal projects by focussing on long term collaboration, flexibility and lifecycle focus.

DBFM elements

Private finance

Not included, because it adds rigidity and financing/transaction premia without clear benefits in high-uncertainty/high-complexity R&R.

Integrated contracting & LCC

Included, because integrating Design–Build–Maintain improves lifecycle optimisation; after realisation the contractor maintains for the lifetime of technical systems (≈10–15 years).

Risk transfer
Included selectively, because early joint risk identification and mitigation allow manageable, known risks to be carried by the contractor while the client retains unpredictable “behind-the-wall’’ risks.

Performance payments & incentives
Included, because targeted incentives (e.g., better LCC or lower design cost) can be rewarded via bonus, shared delta, or increased deal flow (e.g., more objects), During the maintenance phase performance payments can be used but with less harsh penalties.

Governance & client–contractor collaboration
Included, because collaborative governance with transparent communication on risks and costs and proactive contractor signaling supports joint design and decision-making.

Long-term collaboration
Included, because multi-project engagement fosters continuity, learning and resource stability; teams on both client and contractor side remain stable across objects.

Contract components
Delivery system
Integrated DBM in two phases (bouwteam-like): *Exploratory phase* with detailed asset condition assessments, risk assessment and design with pricing finalisation; *Execution phase* with final design, construction, and 10–15 years maintenance.

Reward system
Hybrid pricing: part fixed price, part unit rates, and part provisional/reimbursable in Phase 1. As scope certainty increases, a final price is agreed after Phase 1; a flexible/reimbursable component can remain for genuine “behind the wall’’ unknowns.

Selection procedures
Pre-competitive input on optimal grouping and lot size and on which parts have clear scope (fixed) versus uncertain scope (flexible pricing). Selection is partly based on prices (e.g., unit prices for personnel or fixed-scope items) and partly on qualitative criteria. The goal is to reduce tender cost and time; if workload is high, tender with less competition.

Collaboration model
Collaborative governance focused on joint exploration and design with high collaboration intensity; transparent communication about risks costs and life cycle cost decisions; proactive attitude from contractors to raise concerns and propose improvements.

6.2. Proposal 2: Framework with standardised solutions

Context recap. Lower uncertainty and lower complexity for repetitive assets with similar specifications and interventions, such as many small concrete bridges and viaducts. Repeatability is high and industrialised methods are feasible. Operations and maintenance can be managed through design for maintainability rather than a long maintenance obligation. Market capacity is scarce and benefits from predictable demand and increased volume.

Implements advices: 1, 6, 8, 9, 10, 11, 13, 14, 16, 17, 18.

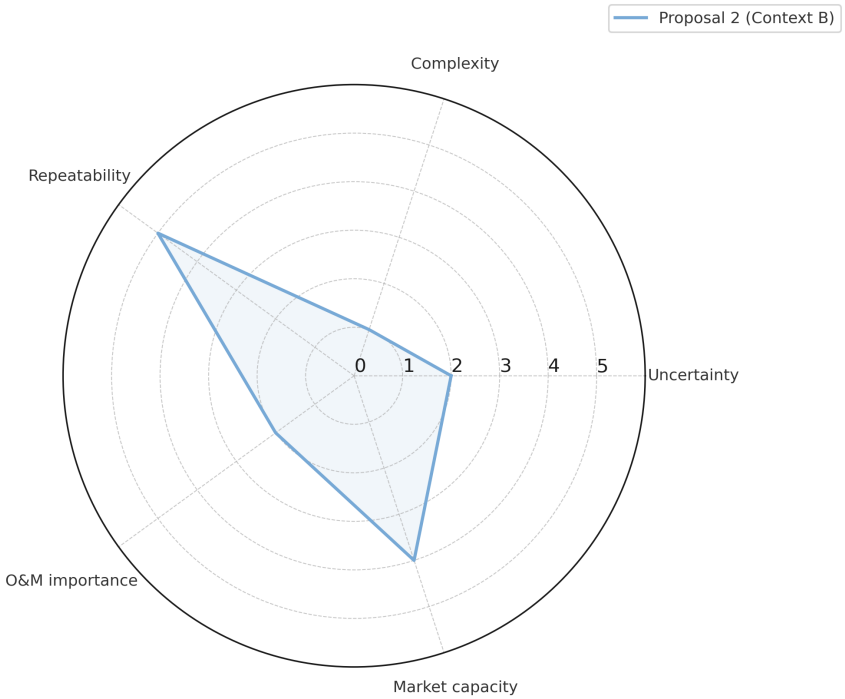

Figure 6.2: Context profile for Proposal 2 (Context B).

Purpose of this model. The model aims to create a repeatable production system that increases throughput and reduces unit costs by using industrialised construction methods. A framework with standard solutions reduces the cost of tendering, engineering, and construction. Contractors design and build assets using standard components or predefined options. Prices per standard object type give clarity, while unit rates cover site specific work. Contractor client collaboration is important to make clear objectives and specifications for the framework agreement, but can be lighter after awarding because the solution space is clear. Simple incentives can reward faster delivery, and a periodic ranking can link good performance to a larger share of work. This approach uses scale and repetition to deliver more objects with stable teams and a predictable planning, while keeping quality and safety consistent and using a more relational based collaboration.

DBFM elements

Private finance
Not included, because it is unnecessary and adds transaction costs in this repetitive setting.

Integrated contracting & LCC
Partly included (Design & Build), because standardised, modular designs reduce lifecycle costs; maintenance can be contracted separately to a maintenance company as the benefits of including it are minimal.

Risk transfer
Included (larger fixed share), because lower complexity and standardised components reduce uncertainty, allowing more scope to be priced and less risk to be retained by the client.

Performance payments & incentives
Included, because fixed unit prices incentivise efficiency and bonuses can be linked to accelerated delivery; incentives can also reward additional work within the framework.

Governance & client–contractor collaboration
Partially Included, no need for complex governance structure. However, there is need for collaboration, but once framework agreement is in place, day-to-day collaboration can be lighter as the solution space is predefined.

Long-term collaboration
Included, because collaboration across multiple projects promotes efficient use of resources and improved learning curves.

Contract components

Delivery system
Framework agreement with standardised solutions: contractors design and construct using standardised components or predefined options. Maintenance can be contracted separately in larger bundles.

Reward system
Fixed price per standard object type; price flexibility (unit rates) for site-specific context; efficiency and performance-based bonuses.

Selection procedures
Pre-competitive input on optimal grouping and bundle size. Selection based on available capacity, price per object and past performance. Within the framework, a ranking determines the share of projects contractors get awarded; ranking is based on past performance and price and will be updated periodically.

Collaboration model
Long-term framework with multiple contractors; allocation of projects or bundles based on capacity and past performance. Because the solution space is predefined, design and execution require less intensive collaboration while maintaining strong transparency.

6.3. Proposal 3: Budget driven, open-book portfolio

Context recap. A fixed budget must deliver as much verified renewal and replacement as possible across a bundle of assets. Uncertainty and complexity differ per object but can be handled with joint planning and sequencing. Repeatability is medium by using modular scoping and standard details. A partial maintain responsibility during the contract protects early life performance and handover quality. Market capacity is limited and benefits from smoothing demand and sharing priorities.

Implements advices: 1, 3, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15.

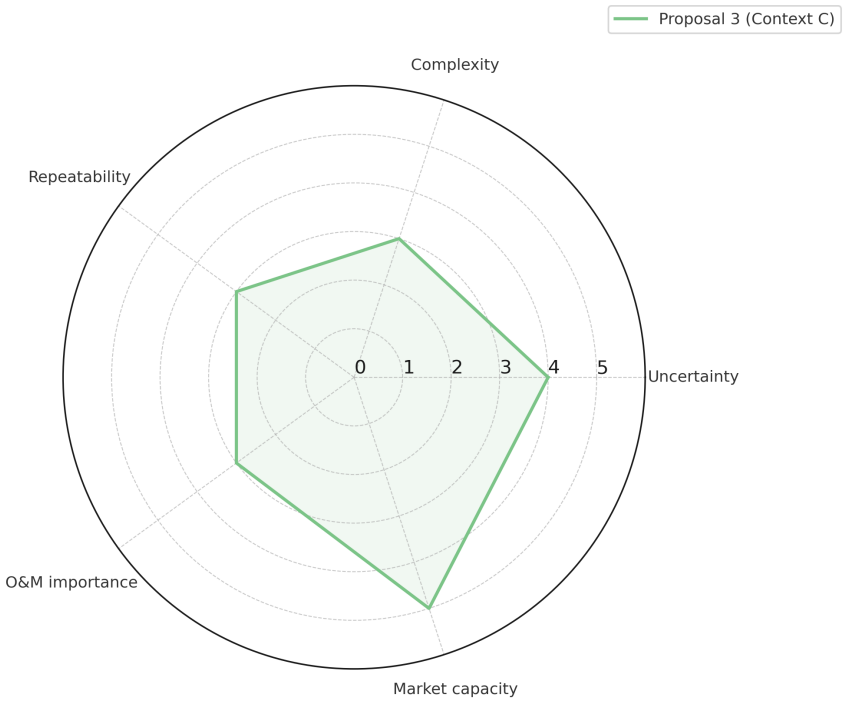

Figure 6.3: Context profile for Proposal 3 (Context C).

Purpose of this model. The model aims to turn a fixed budget into maximum outputs and good value for money. Client and contractor make a renewal plan and sequence interventions together. Open book target cost with gain and pain share aligns incentives. A partial maintain responsibility focuses on increased availability and interventions focused on lifecycle outcome. Risks and rewards are balanced within the open book approach. This approach effectively uses and smooths scarce resources, while also guaranteeing functional assets using transparent collaboration methods.

DBFM elements

Private finance
Not included, because it is not applicable here and would add rigidity.

Integrated contracting & LCC
Included, because during the contract the contractor is responsible for functional assets, aligning design choices and interventions with lifecycle outcomes. This includes the maintenance during contract time.

Risk transfer
Included partially, because significant risks and rewards are shared between client and contractor within a target-cost/open-book approach, the risk transfer is more balanced.

Performance payments & incentives
Included, because open-book, performance-based bonuses can be tied to measurable output and value created within the fixed budget. Incentives should be placed on aligning client and contractor goals because this is not automaticity the case with open-book mechanisms.

Governance & client–contractor collaboration
Included partially, no real SPC but intensive collaboration and agreement on renewal plans are needed with transparency on risk and cost. Can be seen as a sort of alliance.

Long-term collaboration
Included, because a long-term agreement enables sequencing and resource smoothing and allows rewarding future projects after completion.

Contract components

Delivery system
Design Build and partially Maintain. The client provides a fixed budget; the contractor prepares a plan for design and construction of renewals/replacements and, after client approval, executes it to maximise output within the envelope. During contract also responsible for maintenance of objects.

Reward system
Open-book target cost with gain/pain share. Performance-based bonuses relate to effective and efficient renewal/replacement within budget.

Selection procedures
Pre-competitive input on grouping of assets and uncertainty. Rewarded based on Best price–quality ratio based on target price and qualitative criteria.

Collaboration model
Intensive collaboration and agreement on the renewal plan; transparency about risk and cost especially in the planning/design stage. After the interventions are agreed, collaboration can be lighter with more traditional oversight during execution. Can be seen as a sort of alliance where decisions and gain/pain are shared by client and contractor.

Closing Remark

While the three proposed collaboration models offer structured approaches to managing renovation and replacement projects, it is important to emphasise that there is no one-size-fits-all solution. The effectiveness of each model is highly context dependent, influenced by factors such as asset complexity, project scale, market capacity, market willingness to take on risk, and the maturity of standardised construction.

In practice, many hybrid or intermediate solutions are possible. For instance, between Proposal 1 and Proposal 2, there is room for models that utilise framework agreements for more complex objects without relying on full standardisation. In such cases, the inclusion of a maintenance component might be beneficial but could also be contracted separately depending on market preferences and client capacity.

The proposed models are not fixed templates, but starting points that need further investigation. Ultimately designing an effective procurement and contract strategy requires carefully aligning the contract model with project characteristics, stakeholder capabilities, and broader policy goals. As such, the ability to tailor, combine, and evolve models in response to specific project needs is important. This decision making framework and the three collaboration proposals can help in this process.

7

Discussion

This chapter initiates the final phase of the research. The chapter is organised as follows: Section 7.1 revisits the study's purpose and research questions to anchor the discussion. Section 7.2 provides a general reflection that positions the findings within the broader literature and the empirical context of Replacement and Renovation projects. Section 7.3 evaluates the applicability of the results and the decision making framework, including the contract proposals, for different context archetypes. Section 7.4 reflects on limitations stemming from the research design and methods, and outlines directions for further research.

7.1. Purpose of the Study

The study set out to explore how the principles that underpin DBFM contracts can be used to improve the procurement and delivery of Replacement and Renovation projects in the Netherlands. Rather than evaluating DBFM as a single contract form, the research reframed DBFM as a modular set of design principles that can be selectively adapted to the characteristics of R&R work. The decision making framework operationalises this view and links context dimensions to advice to concrete design choices. The central question guiding this effort was: How can the principles of DBFM contracts be used to improve Replacement and Renovation projects in Dutch infrastructure? This was explored through sub-questions on the scope and characteristics of the R&R task, the nature and effects of the DBFM elements, their perceived applicability for R&R by public and private actors, and the translation of these insights into a decision making framework, and improved contract proposals.

7.2. Implications of research findings

The results indicate that DBFM should be approached as a set of design principles rather than a single contract form. In R&R, value arises when principles are tailored to context through integration of life cycle focus, careful risk sharing and fit-for-purpose pricing, targeted incentives, and structured collaboration. This aligns with procurement theory that decomposes procurement into the delivery system, reward system, contractor selection, and collaboration model, which can be recombined to fit project characteristics (Eriksson, 2017). The decision making framework operationalises this principle-based view by linking context dimensions to actionable advice and tracing a path from context to advice to contract design (see Table 5.2).

7.2.1. Characteristics of R&R

The literature characterises R&R in the Dutch context by (i) ageing assets with life-cycle exceedance and deferred maintenance coming due, (ii) high condition uncertainty with "behind-the-wall" defects revealed only after inspection or project realisation, (iii) working in an operational context with availability requirements, (iv) dense stakeholder and permit environments, and (v) capacity constraints in the market (Rasker et al., 2023; Rijkswaterstaat & Wijnen, 2024). The interviews added the characteristics of increased complexity of structures and their technical systems and underscored the other

characteristics.

7.2.2. Implications per DBFM element

Private finance. Literature links private finance to budgetary flexibility and external financial discipline, but also documents higher capital costs and substantial transaction costs that reduce suitability when scope is uncertain and adaptability is needed (Engel et al., 2010; Wijnker et al., 2019; Yescombe & Farquharson, 2018). Consistent with this, interviews and framework logic converge on a limited role for private finance in Dutch R&R. Because of the uncertainty and complexity related to R&R. If applied for policy reasons, first stabilise scope and price via public funds with a two-phase approach before introducing finance.

Integrated contracting and life cycle focus. Integrating design, build, and maintenance, supports Lifecycle optimisation and earlier inclusion of maintenance expertise. This is consistent with literature from (J. Koppenjan et al., 2022; Lenferink et al., 2012) The interviews add that Benefits increase with higher O&M importance and with complexity where system interfaces are decisive. In R&R this often points to DBM with a system-life maintenance horizon rather than full DBFM.

Risk transfer and price mechanisms. Theory supports allocating risk to the party best able to manage it (Bennett & Iossa, 2006). In practice this means substantial risks where transferred to the contractor, incentivise them to manage these risks. Interviewees noted that in R&R substantial risk transfer is appropriate only for predictable and controllable risks; unpredictable risks should remain with the client until jointly diagnosed. A phased set-up with early risk identification allows predictable risks to sit with the contractor while the client retains ”behind-the-wall” unknowns; a mix of fixed items, unit rates, and reimbursable components balances flexibility with price certainty and mitigates defensive pricing (Eriksson, 2017; J. Koppenjan et al., 2022).

Performance payments and incentives. Output-based incentives can align behaviour when they target outcomes that matter in R&R such as availability, efficiency, and life-cycle improvements Promises of future work must be credible within a programme to steer behaviour and sustain improvement. These findings are consistent with literature (J. Koppenjan et al., 2022). However interviews add that harsh performance dependent payments are not suited for R&R.

Governance and collaboration. Early market involvement, open communication on risks and opportunities, enable better scoping, pricing, and delivery. These findings are supported by literature (Benítez-Ávila et al., 2018; Demirel et al., 2021). The interviews added that stronger client-side technical expertise will help with better collaboration and joint decision making.

Long-term collaboration. Stable teams and long-term collaboration can enhance projects outcome (Grimsey & Lewis, 2004b; Huxham & Vangen, 2013). Interviews noted that long term collaboration and especially predictable deal flow increase productivity through learning and smoother resource planning. Framework agreements for long term collaboration are seen as promising to support this.

7.2.3. Implications for programmatic and industrialised delivery

Given the R&R characteristics of combine scale, pockets of repetition, and capacity constraints, a programmatic and industrialised delivery mode is well suited and in many cases necessary to raise throughput while safeguarding availability. Bundling similar objects reduces transaction costs, accelerates learning, and supports predictable deployment of people and plant, provided bundle size preserves competition and market access. The interview finding echo the research of (Brady & Davies, 2004; Estache & Iimi, 2011; Tomczak & Jaśkowski, 2022). Standardisation and modularisation shorten delivery times and lower unit costs where assets are numerous and similar; benefits scale with a credible multi year pipeline and standardised solutions. To increase the scale and volume and thus the applicability of programmatic and industrialised delivery it is important that different government levels standardise and collaborate more for R&R projects.

7.3. Applicability of the research and framework

The applicability of the framework arises from its dual foundation in the literature review and in empirical insights from Dutch public and private actors involved in R&R. The framework is designed to be both theoretically grounded and directly usable by public infrastructure owners who must renew assets while safeguarding availability and managing capacity constraints. It operationalises a principle based view of DBFM by linking context dimensions to concrete advice and coherent contract configurations. Consistent with procurement theory that decomposes procurement into delivery system, reward system, contractor selection, and collaboration model (Eriksson, 2017). The research and framework are tailored to the Dutch context. Because the context determines the challenges and thus the advises that accommodate these challenges it is difficult to transfer the result to other another context. Furthermore, the framework and collaboration proposals are not definitive solutions but a starting point to design a suitable collaboration model for a specific context.

7.4. Research limitations

The scope and methods entail several limitations:

- **Qualitative design without counterfactuals.** The study synthesises interviews and literature; it does not provide econometric estimates of effects on cost, time, availability, or life-cycle outcomes. Propositions on mixed pricing, two-phase working, and incentive design remain theory-informed and interview-supported.
- **Sample composition.** While both client and contractor perspectives are included, financiers and engineering firms are under-represented. This may bias interpretations. Furthermore, most interviews where conducted with people in managerial positions which can miss the operational applicability of the research.
- **Stage of programmes.** Several programmes and frameworks discussed were in early stages, so observed repetition and learning effects are prospective rather than measured over multiple cycles.
- **Mode of interviewing.** A proportion of interviews were conducted online for scheduling efficiency, which may reduce non-verbal cues and contextual richness compared to in-person sessions.
- **Calibration needs.** Thresholds for activating advice (e.g., “how much repeatability is enough” for frameworks, or “how much uncertainty warrants two-phase contract”) are qualitatively argued. If possible practitioners should calibrate these thresholds.
- **Evaluation**, Unfortunately, due to the availability of experts, it was not possible to organise one focus group to evaluate the initial framework.

8

Conclusion and Recommendations

The research objective was to increase understanding of the DBFM elements that can improve Replacement and Renovation (R&R) projects and collaboration between public clients and contractors. This chapter first addresses the the sub questions in Section 8.1, then the main research question is answered in Section 8.2. Finally, it presents recommendations for public clients and contractors and suggests directions for future research in Section 8.3.

8.1. Answers to the sub-questions

8.1.1. Sub-question 1: What are the scope and characteristics of the Replacement and Renovation task?

The Dutch R&R scope has certain characteristics and opportunities. These challenges and opportunities influence the decision on effective contract and collaboration models. Because of this, it is important to distinguish these characteristics and opportunities. **Uncertainty.** There is a lot of uncertainty regarding the state of the infrastructure. Because of poor monitoring systems and unavailable object data there are unknowns and ”behind the wall” risks that make it difficult to have a clear scope, price and planning from the beginning. Due to this uncertainty related to R&R it is important to have flexibility and balanced risk distribution in your contract design.

Operational continuity and availability: Renewal projects always take place in an operational system. Interventions must take into account network availability and safety to minimise disturbance.

Multi actor governance: Many owners, operators, users and regulators hold decision rights in R&R context. This makes decision making more complex. This is further emphasised with strict regulation regarding the environment, for example.

Scarcity of people, time and materials: Market capacity and budgets are tight. Meaning there are labour shortages and budget constraints which limit output. This further emphasises the need for a more efficient approach to R&R.

Complexity because of system integration: The importance of technical systems becomes larger in infrastructure objects. This increases complexity because infrastructure becomes multidisciplinary meaning more and different expertise is needed.

Volume of work: The volume of assets that need intervention coming decades is enormous. This also calls for a different approach that does not handle the problem in a project based manner but on programme basis.

Opportunity of programmatic approach and Industrialisation: Due to the high volume of work this can be an opportunity or necessity to change from a unique project focused industry and transform to a programmatic approach with more standardisation. This will increase speed, cost efficiency and quality and safety.

8.1.2. Sub-question 2: What elements does a DBFM contract consist of and what are the contract design principles behind them?

This study distinguishes six DBFM elements and their design principles:

Private Finance: Private finance ensures financial discipline and better risk management of contractors. It can act as a ”watchdog” and lower additional work order from contractors. Furthermore, it can be used as supplementary funding if public budgets are not sufficient. This can be beneficial in the R&R context as there is limited public budget available. Private finance on the other hand also has downsides and limitations. Private finance often has a higher cost of capital compared to publicly funded projects. Furthermore, because of the introduction of banks which have risk averse behaviour the contracts become inflexible and scope changes are difficult.

Integrated contracts: The idea behind integrated contracts is to optimise lifecycle cost. Because one consortium is responsible for design, realisation and maintenance they have a incentive to make smart design and building decisions that focus on lowering total lifecycle cost including the operational and maintenance phase. This is applicable for the R&R context because it promotes cost efficient asset management. In addition, it can also have a positive effect on sustainability. The downsides which should be considered are the increased complexity and size of projects. Moreover, both client and contractor enter long term collaboration, which reduced flexibility.

Risk allocation: The principle behind the transfer of risk from the client to the contractor is the optimal risk allocation to the party able to best manage the risk. This often resulted in considerable risks that where transferred to the contractor. By doing this the knowledge and expertise of the private sector is used optimal. This also results in better risk management and mitigation which should lead to improved project delivery. The downside of substantial risk transfer is reduced control by public client and reduced contractor interest to bid on tenders, because of the increased risk.

Performance payments and incentives: The principle is to link remuneration to outcomes rather than inputs. Payments are tied to availability of the network which also positively impacting safety, quality and hindrance reduction. This aligns contractor and clients goals. In the R&R context this can mean proactive maintenance and the use of sustainable materials. This will result in higher infrastructure availability and quality. The downsides are defensive behaviour to avoid high penalties. And increased risk for contractors. Furthermore, it makes the contract strict and output based, thus decreasing flexibility.

Long term collaboration: Due to the long term cooperation between client and contractor the benefits of learning and trust building are increased. Long term collaboration suits the R&R context, as the challenge will persist for decades. A Long time horizon is important to deal with the challenges as effective as possible. Potential negative effects of long term collaboration are the reduced flexibility and higher transaction cost.

Governance and client–contractor collaboration: The principle is to define roles, decision rights and information flows that enable timely decisions and shared problem solving. For the R&R it can be beneficial to have clear roles and responsibilities. However, the governance structure can distance the public client from design choices and increase transaction cost.

8.1.3. Sub-question 3: Which design principles of DBFM can be used for replacement and renovation tasks?

Private finance: Private finance is mostly seen as unsuitable for R&R projects, this is mainly due to the uncertainty involved in these projects. Because of this a clear scope and price are hard to determine before hand which is vital for using private finance. The benefit of the controlling function of bankers, which lead to a better cost performance, does not out way the inflexibility associated with this type of project finance. Furthermore, the real bottleneck does not seem to be funding which further lowers applicability. If private finance is needed in the future, because political reasons or because of the controlling function, introduce private finance after the project can have a clear scope and price. This can be done by using a phased project delivery where public funding is used for the first phase, after which private finance can be introduced for the realisation and maintenance phase.

Integrated contracts and life cycle optimisation: This design principle is applicable for R&R tasks.

By involving maintenance expertise from the start, life cycle cost and maintainability can be improved. Furthermore, it can in some cases be beneficial to include a maintenance phase in the contract. By doing this the contractor are incentivise to improve life cycle cost. This becomes increasingly beneficial in projects where the operational and maintenance phase is most important. This is often the case in assets that have technical systems. Maintenance period of the contract should be based on the lifetime of such systems which are approximately around 10-15 years.

Risk allocation: The design principle of allocating risk to party best able to manage it is applicable but there should be a fair risk balance between the client and the contractor. Due to the complexity and uncertainty of R&R it is important to design a collaboration that is more flexible. This can be done by using phased contracts and flexible pricing. Use the first phase to explore unknown conditions and de-risk the project. After the first phase match pricing to residual risk, for example fixed price for well-defined scope, unit rates for variable quantities, and reimbursable pricing for unknowns. Because of the characteristics of R&R projects the client should retain certain ”behind the wall” risks that cannot be effectively managed.

Performance payments and incentives: Applicable to align client and contractor goals. Tie payments and bonuses to availability, safety, hindrance reduction, reliability and life cycle outcomes depending on clients project goals. Use bonuses rather then penalties to avoid defensive behaviour. Bonuses that guarantee follow up projects and consistent deal flow are promising. Performance payments related to availability with high penalties are seen as less optimal. They tend to lead to excessive focus on speed and penalties tend to encourage damage control rather than proactive optimisation. In addition, they can financially hurt the contractor without providing real benefit to the client.

Long term collaboration: This DBFM elements is extremely important especially when combined with a programmatic approach that bundles similar objects. The use of multi-year frameworks agreements focuses on long term collaboration which can help keep teams consistent across similar tasks and to standardise methods and processes. Furthermore, this enables a better learning curve, supply chain investment and smoother mobilisation of people and materials. Long term collaboration also ensures a consistent and reliable deal flow which is important for contractors to invest in people, machinery, innovations and industrialisation.

Governance and client and contractor collaboration: For R&R, a complex governance structure with an SPC, EPC, and MTC is often unnecessary when private finance is not used. Without the interface with debt and equity providers, governance can be simplified. In such settings, it remains important to keep the public client actively engaged in decision making, rather than distanced as in SPC based DBFM structures. Close collaboration and proactive communication about risks and opportunities can improve project outcomes. It also allows the client to retain selected risks, influence key decisions, and maintain control over results.

Programmatic approach A programmatic approach is applicable for R&R tasks that show repetition across objects, corridors or regions. By bundling similar work, transaction costs decrease, learning accelerates and resources can be planned more smoothly across projects. Framework agreements can help keep teams consistent and enable long term planning. This improves predictability and a steady deal flow supports supplier investment in people, tooling and innovation. Strong client side governance remains essential to safeguard quality and maintain competitive pressure. Furthermore, it is important to look at the whole supply chain instead of only contractors. Identifying and resolving bottlenecks in the whole supply chain can improve efficiency, long term planning and resource allocation.

Industrialised construction Industrialised and standardised construction is applicable where scopes allow repeatable solutions. Using modular components, off site fabrication and design for manufacture and assembly reduces design effort, shortens on site time and improves safety and quality, which lowers life cycle cost. To unlock these benefits, early involvement of contractors and key suppliers is needed to align design choices and logistics. Furthermore, upfront investment and cultural resistance are common barriers and are best addressed by a clear pipeline, measurable performance targets and incentives that reward adoption and continuous improvement. The approach works best when combined with programmatic bundling, so that volume, learning and stable demand justify the required investments, while retaining flexibility for site specific constraints. To increase the volume and thus the applicability of industrialised construction, public clients can work together to promote standardisation

across public clients.

8.1.4. Sub-question 4: How can DBFM principles improve renovation and replacement collaboration?

Based on the conducted interviews and literature studies a set of 18 advices based on the six DBFM elements plus the programmatic approach and industrialised construction where presented. These advices take into account the specific characteristics of R&R projects and try to improve client contractor collaboration. The table with advices can be found in Table 5.1.

8.2. Answer to the main research question

How can DBFM principles be used to improve contract design for replacement and renovation projects in Dutch infrastructure?

The most effective application is modular rather than a single uniform DBFM model. Because R&R projects differ, contract design should also differ. The contract should be tailored to the characteristics of the project or programme context. The decision making framework presented in this thesis supports public clients in selecting a suitable form of collaboration based on the project context.

First, the characteristics behind SQ1 are translated into five context dimensions: uncertainty, complexity, repeatability, importance of O&M, and scarce market capacity. Every project or programme can be profiled on these dimensions. Based on that profile, specific recommendations on the use of DBFM elements, the programme approach and industrialised construction are activated. This advice can then be translated into a contract type suitable for the given context.

The framework is demonstrated for three distinct contexts that lead to three different contract proposals. Together, the proposals show how different combinations of DBFM principles fit different situations. Each proposal combines applicable DBFM elements with four contract components: delivery system, reward system, contractor selection procedure and collaboration model.

Overview of proposals and when they fit

- **Proposal 1: Two phase integrated DBM with a system life maintenance horizon.**
  Fits when: high uncertainty, high complexity, low repeatability, medium–high O&M importance, and medium market capacity.
  Focus: fair and explicit risk management, flexibility for uncertainty, and life cycle cost focus.
- **Proposal 2: Framework agreement with standardised solutions and industrialised methods.**
  Fits when: high repeatability, low complexity and low–medium uncertainty, with relatively scarce market capacity.
  Focus: standardisation, prefabrication and efficient throughput using fixed prices for standard items and unit rates for variants.
- **Proposal 3: Budget driven open book portfolio with target cost and gain–pain sharing.**
  Fits when: high uncertainty and high scarcity of market capacity, with other dimensions around medium.
  Focus: maximising output within a fixed budget through transparent collaboration and joint decision making.

These proposals should be seen as indicative. In practice, hybrids or intermediate configurations are often preferable depending on context. Ultimately, designing an effective procurement and contract strategy requires aligning the contract model with project characteristics, stakeholder capabilities and broader policy goals. The decision making framework and the three collaboration proposals provide a structured route from context to advice to contract design to support that alignment.

8.3. Recommendations

In addition to the advices mentioned in the framework, recommendations for public clients and contractors, and for future research are given below.

8.3.1. For public clients

- **Prioritize renewal projects and create a long term plan and forecast.** Establish a robust prioritisation of infrastructure renewals and derive a long term plan and forecast. This plan is crucial for the supply chain, enabling capacity planning and early identification of bottlenecks. Avoid systematically deferring renewals, since the peak of R&R activity is expected in the coming decade. When future problems are foreseeable, bring projects forward to smooth the workload. Align current maintenance strategies with anticipated renewal dates.
- **Manage the whole supply chain.** Effective programme management looks beyond client–contractor collaboration and considers the entire supply chain. Involve key suppliers and manufacturers of critical materials, and ensure that capacity across the chain can meet the workload of the coming decades. Investments in industrialised construction and capacity expansion take time, so start early.
- **Give greater priority to a programmatic approach and standardised solutions.** Current public client practice often focuses on bundling projects to capture learning effects and keep teams consistent. This helps with complex projects, but many smaller bridges cannot be procured in the same way. These high volumes objects, especially at provincial and municipal level call for standardised solutions and a different approach. Developing these standards with all key partners takes time and should receive more priority, including coordination and standardisation across different levels of government.
- **Provide predictable deal flow and act as a reliable client.** Planning and a steady pipeline are vital for the market. Limit political interference that disrupts budgets and schedules. Long term contracts with clear commitments help, and a national renewal fund dedicated to infrastructure renewal could further stabilise financing.

8.3.2. For contractors

- **Give more priority to total life cycle thinking.** Focussing on total LCC and integrated maintenance expertise into design and construction teams can help reduce fragmentation and improve total life cycle cost and sustainability. The maintenance phase in projects often is subordinate to the realisation phase which should not be the case. life cycle thinking can also improve sustainability and modularity which are important topics for the construction industry.
- **Focus on the long term.** As the R&R challenge is long term and the sector is moving toward more relational governance, contractors should maintain a long term perspective and avoid opportunistic behaviour that can damage trust across the industry.
- **Move towards a programmatic and industrialised approach.** Together with clients try to move towards a programmatic and industrialised approach. Be clear which volumes, guarantees and processes are needed for the supply chain to improve efficiency and invest in innovative solutions to effectively manage the R&R task. Contractors should also invest in industrialised construction and building information management to improve project delivery.

8.3.3. For future research

- **Less competitive market.** During the interviews it was noted that, due to the volume of work and scarce market capacity, some work could be tendered in a less competitive environment and divided among contractors. This may reduce tender costs and refocus attention on the R&R task. However, competition also helps ensure effective use of public budgets and keeps prices competitive. Research could examine the effects of lowering competition and whether this would be beneficial in the current R&R context.
- **Design and performance of incentives.** During the interviews, incentives were seen as an important tool to align client and contractor goals. Which incentives are effective in different scenarios is something that can be studied further. Furthermore, the effects of using incentives which award future work are seen as promising and can be studied further.
- **Applicability for smaller municipalities and contractors.** Due to the focus on DBFM elements, most interview participants were from larger municipalities, provinces, national government, and the bigger contractors. Yet a large share of renewal projects is undertaken by smaller munici-

palities working with local SME contractors. Follow-up research could investigate whether the advice and the decision making framework are also useful for smaller municipalities and SME contractors, and whether the advice should be adapted or supplemented.

- **Calibrating the decision making framework.** Further research could quantify thresholds for the decision making framework. For example, how much repetition is sufficient to realise the benefits of framework agreements, or at what share of operational cost integrating maintenance into the contract becomes beneficial.
- **Public client capability.** One factor influencing contracting choices is the capability of the public client. Research could determine the minimum staffing, expertise, and governance needed for effective programme steering and a constructive risk dialogue.
- **Effective quantities for programmatic and industrialised approaches.** Research could investigate the preferred and most effective bundle size when using a programmatic approach. Furthermore, research should examine the minimum volumes and the degree of standardisation needed for industrialised construction.
- **Generalisability beyond the Netherlands.** This study is grounded in Dutch law and institutions. Comparative research could test the decision making framework in other European contexts with different procurement traditions and PPP maturity, and determine what adaptations are needed. Factors to examine include national transposition of EU procurement directives, availability and cost of private finance, maturity of industrialised construction supply chains, labour capacity and the age profile of assets.

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A

Interview protocol

A.1. Purpose of the interviews

The aim of the interviews is to gain empirical insights into how principles from DBFM (Design–Build–Finance–Maintain) contracts can potentially improve replacement and renovation (R&R) infrastructure projects in the Netherlands. These interviews will support the analysis of whether and how certain DBFM principles, such as lifecycle thinking, private financing, integrated collaboration, and availability payments, can be adapted for the specific challenges of R&R projects.

The interviews are also intended to identify how public and private actors currently approach collaboration and contract strategies, what their perceived barriers and opportunities are, and how recent developments such as two-phase contracts and portfolio contracts are being received in practice.

Research questions.

- **Main research question:** How can the principles of DBFM contracts be used to improve Replacement and Renovation projects in Dutch infrastructure?
- **Sub-questions:**
  1. What are characteristics of the Replacement and Renovation tasks?
  2. Which principles of DBFM can be used for Replacement and Renovation tasks?

A.2. Methodology

To ensure consistency and relevance across interviews, the following steps will be taken:

1. **Interview question development**
   Questions are drawn from the theoretical framework and aligned with the main and sub-research questions. Two slightly different interview guides are used: one for public clients and one for private contractors.
2. **Interviewee selection**
   Public sector: Individuals involved in infrastructure procurement, contract management of R&R within municipalities, provinces or Rijkswaterstaat.
   Private sector: Individuals working at infrastructure contractors with experience in DBFM contracts and R&R projects that are involved with tender decisions and contract management.
3. **Approach strategy**
   Interviewees are approached via email, often through personal networks or referrals. The email briefly introduces the research and invites participation in a 60-minute interview.
4. **Interview execution**
   Interviews are conducted either in person or online (via MS Teams), recorded with permission, and guided by a semi-structured question set.

5. **Processing the interviews**
   Interviews are transcribed, anonymised, and coded using thematic analysis.
6. **Utilization of findings**
   Results from the interviews will be synthesised to answer the research question and sub-questions.

A.3. Selection of interviewees

The selection of respondents was purposive to answer the research questions on the applicability of DBFM principles in replacement and renovation projects. We aimed for variation in type of organisation, and role so that both strategic and operational perspectives are represented, but with a focus on frot end decision making. The sample includes public clients and private contractors.

Selection criteria

- **Relevant experience:** demonstrable involvement in R&R projects or DBFM projects, and experience with two phase or portfolio procurement.
- **Decision making** focus on strategic decision makers (directors, procurement and contract managers) that are involved in the front end decisions. For public clients this means decisions based on how to procure certain projects/programmes. For contractors this means strategic decision making about bid/no bid decisions.

Profiles and rationale for approach

- **Public clients** (national agency, provinces, municipalities): asset managers and programme managers for insight into availability requirements and portfolio contracting. Procurement and contracting advisers where involved for their role in selecting the collaboration form and price mechanism.
- **Private contractors**: Tender and project managers for risk assessment and bid or no bid decisions; contract managers for experience with performance commitments and life cycle optimisation.

A.4. Ethics, informed consent and data handling

This interview is part of a master's research project at Delft University of Technology, conducted by Bram van Oord. Information obtained during the interviews will be recorded through audio recordings and written notes. Prior to each interview, participants are asked to sign an informed consent form explaining the purpose of the interviews and how data will be handled. Recordings are used only to prepare transcripts. Transcripts will be shared with participants for approval; after approval they will be used for data analysis. Audio recordings will be deleted after transcription. Data are stored securely and processed in anonymised form.

A.5. Interview protocol (Publieke opdrachtgever)

Deel I: Introductie

Allereerst wordt de geïnterviewde bedankt voor zijn of haar deelname aan het onderzoek. Vervolgens introduceert Bram zichzelf, het onderwerp en het doel van het onderzoek. Daarbij wordt aangegeven dat het interview circa 60 minuten zal duren. Er wordt gevraagd of de geïnterviewde akkoord is met het maken van een audio-opname. Na afloop van het interview ontvangt de geïnterviewde een samenvatting van het gesprek (de transcriptie), met de vraag of deze akkoord is met de inhoud.

Deel II: Interviewvragen

1. **Achtergrondvragen**
   - Wat is uw rol binnen de organisatie? (vanuit welk perspectief beantwoord u de vragen?)
2. **Vervanging & Renovatie (VenR)**

- Wat zijn volgens u de belangrijkste verschillen tussen VenR-opgaven en nieuwbouwprojecten?
- Wat is het doel van VenR-projecten? (Alleen de huidige infrastructuur instant houden of wordt er ook gekeken naar meerwaarde realiseren op het gebied van duurzaamheid functionaliteit en andere publieke meerwaarde? Kansen benutten)

3. **Aanbesteding en samenwerking**
   - Welke aspecten worden afgewogen bij het besluitvormingsproces van een keuze voor een samenwerkingsvorm? En welke zijn specifiek voor de VenR het belangrijkst
   - Wanneer beschouwt u een aanbesteding als succesvol? Wat is het doel van een succesvolle contractkeuze of samenwerking? En wanneer is een aanbesteding een minder succesvol? En ligt dit aan de contractkeuze of samenwerking of andere elementen?
   - Heeft de huidige contractvorm/samenwerkingvorm tussen publiek en privaat een houdbaarheidsdatum hoelang kan het nog mee?
4. **DBFM (Design, Build, Finance, Maintain)**
   - Heeft u/uw organisatie ervaring met DBFM-contracten of -projecten?
   - Wat ziet u als de voor en na delen van het werken met DBFM-contracten?
   - Welke elementen uit DBFM-contracten zouden volgens u kunnen bijdragen aan het succes van VenR-opgaven? Welke fasen of snijvlakken zijn kritiek?
   - Welke DBFM elementen belemmeren dat deze samenwerkingsvorm gebruikt kan worden voor de VenR opgaven?
5. **Portfolio contracten**
   - Wat is de impact van het bundelen van projecten in een portfolio
   - Zou onderhoud ook meegenomen kunnen worden in deze portfolio contracten
6. **Prijs mechanisme**
   - Hoe belangrijk is het prijs mechanisme voor het risico profiel van een project.
   - Hoe belangrijk zijn incentives voor het efficiënt uitvoeren van projecten.
   - Wat vind u van openboek prijsbepalingen zoals kost+ of tweefasen contracten?
   - Hoe kun je zorgen dat bij openboek zoals kost+ of tweefasen contracten genoeg incentive en ruimte is om te innoveren
7. **Open eind vraag**
   - Ziet u mogelijkheden om de samenwerking tussen publieke en private partijen verder te verbeteren?
   - Wat is belangrijke volgende stap om de toekomstige infrastructuur opgaven aan te pakken?

A.6. Interview protocol (Private aannemer)

Deel I: Introductie

Allereerst wordt de geïnterviewde bedankt voor zijn of haar deelname aan het onderzoek. Vervolgens introduceert Bram zichzelf, het onderwerp en het doel van het onderzoek. Daarbij wordt aangegeven dat het interview circa 60 minuten zal duren. Er wordt gevraagd of de geïnterviewde akkoord is met het maken van een audio-opname. Na afloop van het interview ontvangt de geïnterviewde een samenvatting van het gesprek (de transcriptie), met de vraag of deze akkoord is met de inhoud.

Deel II: Interviewvragen

1. **Achtergrondvragen**
   - Wat is u rol binnen de organisatie? En welke ervaring heeft u met DBFM en/of VenR projecten

2. **Vervanging & Renovatie (VenR)**
    - Vormt de VenR-opgave een belangrijk onderdeel van jullie projectportfolio en verwachten jullie dat dit zal toenemen?
    - Wat zijn volgens u de belangrijkste verschillen tussen VenR-opgaven en nieuwbouwprojecten?
    - Wat zijn uitdagingen en kansen bij de VenR opgaven?
3. **Aanbesteding en samenwerking**
    - Wat zijn de belangrijkste voorwaarden in een contract/samenwerkingsvorm die bepalen of jullie wel of niet inschrijven op een tender.
    - Hoe belangrijk is de contract- of samenwerkingsvorm voor het succesvol uitvoeren van VenR-opgaven? En zijn daarnaast nog andere zaken belangrijk.
    - Wat hebben jullie van opdrachtgevers nodig om efficiënt projecten uit te voeren.
4. **DBFM**
    - Heeft uw organisatie ervaring met DBFM-contracten of -projecten?
    - Wat zijn de voor en na delen van het werken met DBFM-contracten?
    - Welke elementen uit DBFM-contracten zouden volgens u kunnen bijdragen aan het succes van VenR-opgaven?
    - Welke DBFM elementen belemmeren dat deze samenwerkingsvorm gebruikt kan worden voor de VenR opgaven?
5. **Portfolio contracten**
    - Wat is de impact van het bundelen van projecten in een portfolio
    - Zou dit nog in een geïntegreerd contract kunnen
6. **Prijs mechanisme**
    - Hoe belangrijk is het prijs mechanisme voor het risico profiel van een project.
    - Hoe belangrijk zijn incentives voor het efficiënt uitvoeren van projecten.
    - Wat vind u van openboek prijsbepalingen zoals kost+ of tweefasen contracten?
    - Hoe kun je zorgen dat bij openboek zoals kost+ of tweefasen contracten genoeg incentive en ruimte is om te innoveren
7. **Open eind vragen**
    - Ziet u kansen om de samenwerking tussen publieke en private partijen te verbeteren?
    - Wat zou er moeten veranderen aan de huidige aanbesteding of contract strategie om de prestatie van VenR projecten te verbeteren?

B

Extended interview analyses

B.1. Analysis: Characteristics, Challenges, and Opportunities of Replacement and Renovation

B.1.1. Characteristics and Challenges of R&R Projects

1. Scope Uncertainty

Both literature (Chang et al., 2003; Straub, 2009) and interviews highlight that R&R projects inherently involve higher uncertainties compared to new construction. Existing structures often hide unknown factors, complicating precise scope definition. This ”behind-the-wall” uncertainty frequently leads to unexpected issues surfacing during project execution [CO5, CL6, CL3, CL1]. This aligns clearly with literature, which emphasises uncertainty as a characteristic in maintenance and renovation contexts (Wang et al., 2021). Both literature and interviews identify asset condition uncertainty as the primary challenge, complicating traditional contract models, risk assessment, and budgeting.

2. Operational Environment

Interviews emphasise the complexity of continuous operational contexts as does the literature (Karydas & Gifun, 2005) noting operational environments significantly constrain construction flexibility, adding complexity and necessitating extensive stakeholder coordination (Hertogh & Westerveld, 2010; Schraven et al., 2011). The literature further emphasises the societal impacts of operational disruption, matching interview findings [CO5, CL6, CO4]. Interviews and literature emphasize the operational environment as a challenge for infrastructure renewal projects, necessitating balance between project efficiency and limited disturbance.

3. Limited Design Flexibility

Interviews noted that existing structural constraints limit design flexibility, because of the already existing context and system [CO4][CL4][CO6]. Literature also highlighted the operational system as a challenge but not particularly the limited design flexibility.

4. Evolving Technical Scope

Some interviews, mainly contractors, emphasise the increasing technical complexity involving mechanical, electrical, and automation components. Literature acknowledges evolving asset complexity, though explicit references to shifts from civil to systems engineering are less prevalent [CO4][CO2][CO3]. Interviews also highlight the need for organisations to adapt to this change.

5. Scale and Volume

Both literature and interviews note the increasing scale and volume of infrastructure projects (Rasker et al., 2023; Rijkswaterstaat & Blom, 2021) [CL3][CL6][CL7][CO1][CO6]. Interviews also note that coming decades less new infrastructure will be built and the focus will shift from greenfield projects to renewal projects. Literature indicates resource constraints generally, focusing on the shortage of skilled labor and competing infrastructure priorities such as energy transition and housing (Rijkswaterstaat & Wijnen, 2024). Interviews confirm these constraints and highlight the need to be attractive for contractors [CL3, CL6].

B.1.2. Opportunities for R&R Projects

1. Standardisation and sed Construction

Literature and interviews strongly concur on the potential for standardised solutions to enhance efficiency, reduce preparation costs, and leverage repetitive tasks for learning (Arnoldussen et al., 2017; Lycett et al., 2003); CL4, CL6, CO1, CO4. They also both underline the potential for strategically bundling similar projects to further increase the learning effect and lower transaction cost. Literature (Gann, 1996; Lawson et al., 2011) extensively supports industrialised construction methods for increased efficiency, quality, and sustainability. Some interviews also support this but less significantly [CL5, CL4, CO4].

2. Upgrade Networks

In the literature, the opportunities to upgrade infrastructure for future demands is given. This includes addressing economic and environmental challenges (Hertogh & Bakker, 2016) and adopting a lifecycle management approach. In the interviews, this was not directly given as an answer to questions about opportunities for renewal projects. This has to do with the scale and volume of the problem, as some interviews noted we cannot change and upgrade all infrastructure with new functionalities because it will increase the complexity, time and cost [CL4][CO1].

B.2. Analysis of DBFM Element: Private Finance

1. Budgetary Constraints and Financing Needs

The literature shows that private finance offers advantages such as mobilising private capital and creating stable long-term budgets that are independent of annual government funding (Wijnker et al., 2019; Yescombe, 2007). In practice, however, interviews indicate that the urgency for private finance is currently low. Dutch authorities have access to relatively cheap financing and view limited market capacity as a greater bottleneck than financing itself [CO1, CO3, CL5, CL7]. This means that although the theoretical benefits of private finance are recognised, these benefits are currently not applicable for the Dutch context.

2. Inflexibility of Private Finance in R&R Projects

The literature states that DBFM contracts can impose rigid structures, leading to limited flexibility in projects with uncertainties such as R&R (Hart, 2003; Marques & Berg, 2010). This is confirmed by interviews, where respondents note that the uncertainty regarding the exact scope of R&R projects is poorly aligned with the strict requirements of private financiers. The inherent characteristics of R&R, such as the uncertainty of what will be encountered during dismantling and the challenges of working in an operational environment, are not well suited to the rigid structure of private financing [CO5][CL1][CO4][CO6].

3. High Transaction and Financing Costs

Both literature and interviews confirm that DBFM contracts involve high financing and transaction costs, mainly due to detailed risk assessments and extensive tender procedures (J. Koppenjan et al., 2022; Yescombe, 2007). Interviewees also stress that these high costs are not contributing to solving the problems and thus are to be lowered, particularly given the large scale of upcoming R&R tasks [CL1, CO3].

4. Benefits of External Financial Control

The literature highlights that private financiers can play a positive role as external overseers who enforce financial discipline leading to on-budget delivery and on-time delivery (Verweij & Van Meerkerk, 2020). Interviews support this view, indicating that private financiers can indeed serve as a useful “watchdog,” ensuring contractors’ performance and preventing unnecessary additional work [CL1, CL4]. This benefit is only regarded by clients and contractors mainly see the downsides of this strict control.

5. Potential Future Need

Both literature and interviews point to an increase in the need for extra finance in the long term. Especially after 2030, when the R&R challenge is expected to intensify (Rijkswaterstaat & Blom, 2021). Some interviews suggest that private finance may become necessary as an alternative tool to mobilise sufficient capital in the future [CO1, CL3].

B.3. Analysis of DBFM Element: Integrated Contracting and Life Cycle Cost (LCC) Optimisation

1. Optimisation of Life Cycle Costs (LCC)
The literature emphasises that integrated contracts incentivise contractors to make cost-effective decisions over the entire life cycle of an asset, rather than focusing solely on initial investments(J. Koppenjan et al., 2022; Yescombe & Farquharson, 2018). Interviews confirm this and highlight that contractors in integrated contracts are incentivised to select sustainable designs and materials with lower long-term maintenance costs [CO1, CO5, CL5, CL1, CO3]. This can be achieved with Design-Build-Maintain (DBM) contracts for R&R projects, where the contractor remains responsible for maintenance for several years after the renovation. This ensures that maintainability is considered during the design and construction phases, resulting in more durable and cost-effective solutions [CO1, CL2, CL3].

2. Suitability for Certain Types of Assets
The interviews indicate that LCC optimisation is particularly effective for assets with shorter life cycles, such as technical installations, while it is less applicable to assets with very long life spans, such as concrete structures [CL3, CL2, CO3]. This is not directly named in the literature butLenferink et al. (2012) illustrates that lifecycle cost optimisation is most effective when maintenance cost can be reduced significantly.

3. Risk of "Asset Depletion"
Interviews express concern about the risk that contractors might "run down" assets toward the end of the maintenance contract [CL3, CL5, CL8]. Interviews also point to the risk of knowledge loss and reduced ownership on the client's side when maintenance and too much responsibility is transferred to the market [CL3, CL7, CL8].

4. Budgetary Constraints of the Government
An additional limitation identified in interviews is the government's annual budgetary system (cash-based accounting). This system hampers the full exploitation of LCC optimisation, as long-term investments are harder to fit within the yearly budget framework [CL1, CL5].

B.4. Analysis of DBFM Element: Risk Transfer

1. Selective Risk Transfer
The literature emphasises that DBFM contracts transfer risks to private parties to stimulate innovation and efficiency (J. F. Koppenjan, 2005). However, interviews indicate that market parties are reluctant to accept certain risks, particularly those related to hidden defects in R&R projects. These risks are perceived as unpredictable and difficult to manage, making private parties more selective in accepting risks [CO1, CO5, CL3, CL2].

2. Innovation and Efficiency through Risk Transfer
According to both literature and interviews, effective risk transfer stimulates innovation and efficiency, as market parties are motivated to proactively manage risks and minimise costs. These positive incentives can result in lower costs and innovative solutions for project execution (Flyvbjerg, 2009) [CO3, CL1, CL4, CO2].

3. Joint Risk Assessment
Both literature and interviews highlight the importance of risks being assigned to the party best positioned to manage them, leading to better collaboration and more efficient project execution (Bennett & Iossa, 2006) . The interviews especially highlight the importance of early involvement of market parties to jointly identify and allocate risks. Furthermore, they also emphasise the role of openness and transparency in risk management [CO1, CO2, CL5, CO4].

4. Strengthened Role of Clients
Interviews reveal that clients need to strengthen their internal expertise in risk management to effectively participate in risk discussions. This enables balanced risk allocation [CL3, CL1, CO1, CO4].

5. Risk of Losing Public Control and Knowledge Loss
Both literature and interviews note the risk of knowledge loss when too many responsibilities are outsourced to private parties (J. Koppenjan et al., 2022). This can lead to a decline in technical expertise

and reduced operational knowledge on the client's side, undermining their role as asset manager [CL2, CL6, CL5, CL4].

B.5. Analysis of DBFM Element: Long-Term Collaboration

1. Learning Effects and Efficiency Gains

Both literature and interviews indicate significant advantages in repeated collaboration, particularly through the learning curve effect. Literature highlights that repeated interactions facilitate knowledge transfer, increase efficiency, and promote continuous improvement (Van De Waerdt et al., 2024). Interviews confirm these advantages, noting that long term collaboration increases teams experience, directly benefiting project outcome (Ghobadian et al., 2004) [CO1, CL3, CL2]. The long term collaboration in DBFM contracts is mainly because of the long term maintenance component. In the interviews, long term collaboration like framework agreements also were mentioned where there is long term collaboration transcending single projects.

2. Predictability and Market Stability

Interviewees stress the value of predictability and continuity provided by long-term contracts, enabling contractors to stabilise revenue streams and efficiently allocate resources and personnel [CO1, CO2, CO4, CO5, CL2]. They emphasise how long-term collaboration fosters stable business environments, thus incentivizing contractors to invest in capacity development and innovation. This is especially relevant for investments in industrialisation which have high initial investments that need to be recouped with enough volume (Mao et al., 2013).

3. Enhanced Trust and Cooperation

Both sources highlight improved trust and effective communication as significant benefits of sustained collaboration. Interviews emphasise the importance of transparency and open communication for addressing risks and managing uncertainties effectively, noting that long-term partnerships facilitate stronger interpersonal relationships, enhancing overall project performance (Ghobadian et al., 2004) [CO1, CO5, CL2].

B.6. Analysis of DBFM Element: Performance Payments and Incentives

1. Promoting Efficiency and Innovation

According to the literature, performance payments and incentives encourage market parties to operate innovatively and efficiently (Lenferink et al., 2012). The goal is to align incentives by rewarding availability. Interviews support this view, indicating that well-designed incentives motivate market parties to seek smart and sustainable solutions and to adopt innovative work methods, resulting in improved project outcomes [CO5, CO1].

2. Specific Bonus Structures

Interviews reveal that specific bonus structures can be implemented to achieve various objectives, such as accelerating project completion and improving sustainability and life cycle costs (LCC). It is emphasised that bonuses are particularly effective when they are focused on timely delivery and on delivering quality that results in longer asset lifespan and enhanced infrastructure sustainability [CO1, CL3, CL4, CL2].

3. Incentives for Future Projects

Interviews highlight that instead of rewarding additional work on the current project, incentives can be designed to grant contractors more work in future projects as a result of good performance [CO2][CL3][CL4]. This encourages contractors to adopt a long-term vision, knowing that efficient and high-quality performance will lead to continuity and future opportunities [CO2][CL3].

4. Risks and Potential Negative Effects

Despite their advantages, both interviews point out the risks and potential negative effects of incentives. Poorly designed incentives may lead to reduced quality and safety risks, particularly if speed is overly rewarded. Moreover, penalties are often considered undesirable, as they contribute little constructively and tend to focus on damage control rather than proactive improvement [CL1, CL3, CO2].

B.7. Analysis: Price Mechanisms for R&R Projects

1. Fixed-Price Mechanisms

Fixed-price contracts provide cost certainty to the client, limiting financial risks related to price escalation (Eriksson, 2017). This is also the case in DBFM contracts. However, interviews indicate significant challenges when applying fixed-price mechanisms to R&R projects, due to the high uncertainty and hidden risks. Unexpected conditions and necessary scope adjustments can quickly result in disputes, additional claims, and cost overruns, making fixed-price contracts less suitable for R&R scenarios [CO1][CL2][CL5][CO2][CO5].

2. Cost-Reimbursable Contracts

Cost-reimbursable mechanisms, such as cost-plus contracts, are flexible and allow contractors to recover actual costs incurred plus a predetermined fee. Interviews indicate this model can accommodate unforeseen issues typical of R&R projects, promoting transparency and collaborative risk management between parties. However, they note potential drawbacks including reduced incentives for cost control and efficiency [CO1][CO5][CL7][CL8].

3. Unit Price (Schedule-of-Rates) Mechanisms

Unit pricing, based on predefined rates for specific tasks or materials, offers a balanced approach. This mechanism aligns well with the repetitive nature of many R&R tasks, allowing flexibility in scope adjustments without extensive renegotiations. Interviews highlight its effectiveness in managing uncertainty while retaining cost transparency and control [CL5, CO3].

Risk of Over-Optimisation in Design:

Two-phase contracts can sometimes result in excessive time and money being spent on design and preparation phases, as parties attempt to eliminate all risks before agreeing on a fixed price [CL3][CL8]. This over-optimisation can delay project execution and reduce efficiency [CO4]. It is essential to find a balance between creating sufficient certainty and starting the works promptly [CL3][CO3][CO4]. Both [CL6] and [CL1] note that although more money may be invested during the initial phases of two-phase contracts, this investment pays off due to improved collaboration throughout the remainder of the project.

B.8. Analysis: Selecting Contractors and Tender Criteria for R&R Projects

1. Shift from Lowest Price to Value-Based Selection

Traditional lowest-price tendering often fails to capture the complexity and risk profile of R&R projects. Literature suggests that awarding contracts purely based on price can lead to suboptimal outcomes, including insufficient quality and strained collaboration (Eriksson, 2017). Interviews confirm this, indicating a shift towards value-based criteria and past performance [CO5, CO1]. This approach incentivise contractors to focus on project-specific solutions and quality rather than cost-cutting. Furthermore, it can reduce tender cost [CL4][CO2][CO3][CO5].

2. Early Contractor Involvement

Bringing contractors on board during the early preparation or exploration phase allows them to contribute their execution knowledge and expertise during design and scope definition. This early input helps to reduce failure costs and avoid surprises later in the process [CL6][CL1][CO2][CL8]. The literature also highlights the benefits of early contractor involvement (Eriksson, 2017). In some cases, this approach may require awarding a project before a fixed price has been fully agreed upon [CL2][CO5][CL7].

B.9. Analysis: Collaboration Between Public Client and Contractor in R&R Projects

1. Trust and Transparency

Literature emphasises the importance of trust as the foundation of successful public-private collaboration (Bresnen & Marshall, 2000). Open communication about costs, risks, and project challenges fosters mutual understanding and problem-solving. Interviews confirm this, highlighting that contractors expect clients to openly discuss risks and avoid opportunistic behavior, while clients demand fair

pricing and proactive communication [CL3, CL1, CO2].

2. Early Contractor Involvement (ECI)
ECI is frequently cited in literature as a means to integrate construction knowledge into early design stages, leading to more feasible and cost-effective solutions (Kadefors et al., 2007). Interviews underscore that early involvement allows for better risk allocation, faster identification of potential bottlenecks, and innovative approaches tailored to project needs [CL4, CL7, CO3].

3. Joint Problem-Solving and Flexibility
Collaboration thrives when both parties engage in joint decision-making and flexible problem-solving. Literature supports the idea of relational contracting, where shared objectives are prioritised over rigid contract enforcement (Eriksson, 2017). Interviewees similarly stress the importance of reducing administrative burdens and focusing on the core project objectives to enhance efficiency [CO4, CO2].

4. Technical Knowledge and Leadership
Interviews identify the technical expertise of the public client as essential for maintaining balanced discussions with contractors. Clients must be capable of assessing proposals, managing risks, and acting as an informed partner. Interviews highlight the need for stronger technical leadership on the client side to ensure collaborative parity [CL3, CO1, CO4].

5. Organisational Alignment and Focus on Core Task
Successful collaboration also depends on cultural alignment between public and private actors. Literature suggests that relational norms such as openness, fairness, and commitment to joint goals significantly improve project outcomes (Suprapto et al., 2014). Interviews echo this, stressing that both parties need to adopt a proactive, solution-oriented mindset [CO3, CL7]. This mindset should be focused on the core task—the renovation and replacement of infrastructure. This also means that more focus should be brought onto the realisation of projects and less on process management and ”pointless” bureaucratic activities [CO4].

B.10. Analysis: Programmatic Approach to R&R Projects

1. Characteristics of Programmatic Management
Programmatic management involves coordinating multiple related projects under a shared strategic framework, aligning them with long-term objectives (Martinsuo & Ahola, 2022). Unlike isolated project management, programmes allow for economies of repetition, systematic learning, and a focus on long-term value creation. Interviews confirm that bundling R&R tasks helps reduce transaction costs, improve planning predictability, and achieve more consistent quality [CO1, CL3, CL6].

2. Efficiency Through Repetition
Both literature and interviews highlight that a programmatic approach leverages the repetitive nature of many R&R tasks, such as the renovation of bridges, locks, or viaducts. Standardised designs and processes can be reused across projects, improving cost-efficiency, reducing preparation time, and enabling continuous improvement [CO1, CL4, CL7, CO4] (Van De Waerdt et al., 2024).

3. Strategic Resource Management
According to Shehu and Akintoye (2009), programme management involves the coordination and allocation of resources, as well as the planning and management of related projects, to achieve outcomes that would not be possible if the projects were managed individually. This perspective on strategic resource use, such as the optimal allocation of materials and personnel, was not explicitly mentioned in the interviews. From the client side, the programmatic approach appears to focus primarily on reducing transaction costs and leveraging learning effects, rather than on strategic resource allocation.

4. Governance and Collaboration
Programme governance is inherently more adaptive and relational than traditional project governance. Literature suggests that effective programme governance relies on shared decision-making, flexible leadership, and clear incentive structures (Shehu & Akintoye, 2009). Interviews underscore that long-term collaboration within programs builds trust and allows for joint problem-solving between clients and contractors [CL2, CO5].

5. Potential Challenges

While the benefits are clear, literature and interviews also warn of potential downsides. Large bundled programs can limit competition, especially for small and medium-sized enterprises (SMEs), and may reduce innovation if only a few large contractors dominate (Estache & Iimi, 2011) [CL3, CL7]. Additionally, programs require strong client-side capacity to coordinate and manage multiple projects simultaneously [CL1, CL6, CL3].

B.11. Analysis: Industrialised and Standardised Construction in R&R Projects

1. Standardisation for Efficiency
Both literature and interviews emphasise that standardisation of components and processes reduces design complexity and enables economies of scale (Lawson et al., 2011). By grouping assets with similar characteristics into families, standardised solutions can be applied repeatedly, leading to lower preparation costs and accelerated project delivery [CL3, CL1, CL7]. This approach is particularly beneficial given the vast number of R&R tasks expected in the coming decades.

2. Modular and Prefabricated Approaches
Prefabrication allows construction elements to be manufactured in controlled environments, improving precision and reducing environmental impact on-site(Jaillon & Poon, 2010). Interviews support this finding, with respondents noting that prefabricated components can streamline construction and maintenance [CO1, CO4].

3. Barriers and Challenges
Despite its benefits, industrialised construction faces several barriers. Literature identifies high initial investment in prefabrication facilities and digital systems as a key challenge (Mao et al., 2013)Interviews add that cultural resistance from both clients and contractors, as well as the fragmented nature of the construction industry, hinder widespread adoption [CL3, CO5]. Furthermore, the design inflexibility associated with standardised systems can conflict with the unique conditions of R&R projects [CL5, CO2].

4. Sustainability and Circularity Opportunities
Industrialised construction enables sustainable practices such as material reuse and reduced waste. Interviews emphasise that modular components can be designed for disassembly and recycling, aligning with circular construction principles and long-term sustainability goals [CL5, CO4]. Literature also highlights the environmental benefits of reduced emissions and noise through off-site production (Chen et al., 2009).

C

Extensive explanation of the decision making framework

C.1. context dimensions rubric

The decision making framework uses five context dimensions that frequently drive fit between project context and procurement choices. Each dimension is defined below with observable indicators and a simple Low–Medium–High rubric.

Uncertainty *What it captures.* The extent of unknown scope, hidden conditions and changeable requirements. *Typical indicators.* Age and condition data gaps, limited inspections, many provisional items, moving external requirements, early design maturity. *Rubric.*

- **Low:** Recent condition surveys, stable requirements, quantities well known, limited provisional items.
- **Medium:** Some gaps in surveys, several provisional items, moderate chance of change during design.
- **High:** Many hidden conditions, limited access for inspection, frequent requirement changes, large provisional allowances.

Complexity *What it captures.* The degree of technical integration and the breadth of institutional interfaces. For transparency, read complexity as the sum of two parts: technical integration of systems and structures, and institutional interdependence across owners, operators and regulators. *Typical indicators.* Number of disciplines and interfaces, safety critical systems, extensive testing, many stakeholders with decision rights. *Rubric.*

- **Low:** Few disciplines, simple interfaces, single asset owner, standard approvals.
- **Medium:** Multiple disciplines, several critical interfaces, some parallel decision paths.
- **High:** Dense systems integration, stringent testing and commissioning, many authorities and owners with shared access or service constraints.

Repeatability *What it captures.* Similarity of objects and work steps and the expected volume of repeats within the programme. *Typical indicators.* Number of assets in the same family, standard details available, ability to reuse methods, opportunity for series production. *Rubric.*

- **Low:** One-off or highly bespoke object, limited reuse of methods.
- **Medium:** Several related objects with partial reuse of details and methods.
- **High:** Many similar objects, strong standardisation potential and clear learning curves.

O&M importance *What it captures.* The relative weight of operations and maintenance in life cycle cost and the importance of availability during use. *Typical indicators.* Share of O&M in total cost, strict availability windows, energy and maintenance intensity, need for maintainability by design. *Rubric.*

- **Low:** Limited service impact from downtime, small O&M share in total cost.
- **Medium:** Noticeable availability requirements, material O&M cost over life.
- **High:** Service is critical, strict access windows, O&M dominates life cycle cost.

Scarce market capacity *What it captures.* The availability of qualified people, key plant, and critical suppliers in the market at the time of delivery. *Typical indicators.* Few credible bidders, long lead times, pressure on specialist crews, supplier bottlenecks, high opportunity cost of downtime. *Rubric.*

- **Low:** Broad bidder field, normal lead times, no binding resource constraints.
- **Medium:** Some pressure on specialist trades or suppliers, lead times rising.
- **High:** Clear scarcity signals, limited bidder field, binding constraints on people, plant or key materials.

C.2. Rationale for context markers

This subsection explains why each advice in Table 5.2 receives a positive or negative marker under the context dimensions. The markers indicate directional fit, not effect size.

1. Avoid using private finance for R&R

- **Uncertainty:** ✓ Financiers require tight scope and risk clarity resulting in a rigid contract; unknowns raise premia and the need for flexibility.
- **Complexity:** ✓ Complexity asks of flexibility in pricing and risk transfer private finance, which is costly and reduces flexibility.

2. If private finance is used, first clarify scope and price

- **Uncertainty:** ✓ Clarify scope becomes increasingly important as uncertainty is high.
- **Complexity:** ✓ Clarifying price becomes increasingly important when project is complex.

3. Give more priority to total LCC from project start

- **Always applicable*:** Giving more priority to total LCC from project start will benefit all projects in terms of maintainability efficient use of resources and sustainability.
- **O&M importance:** ✓ When service and upkeep become important in life cycle cost, early life cycle choices yield larger gains.

4. Make use of integrated contracts

- **Complexity:** ▲ For complex projects the lifecycle cost often becomes more important and thus the integration of maintenance in the contract incentivise contractors to lower total lifecycle cost. But on the other hand an already complex project may become to complex with to much risk to for contractors to commit to a long term DBM contract. Must be considered depending on the situation and market appetite.
- **Repeatability:** ✗ When standardisation becomes the norm, you only have to design this standard once focusing on total cost of the life cycle, but there is no benefit in doing the series all in integrated contract. More efficient to later bundle the finished objects for a separate maintenance contract.
- **O&M importance:** ✓ Integration maintenance become increasingly beneficial when operation and maintenance cost become more important in total life cycle cost.

5. Use phased contracts to jointly reduce risks and unknowns

- **Uncertainty:** ✓ Joint exploration before pricing prevents claims and reduces contractors risk. This becomes increasingly important when uncertainty is high.
- **Complexity:** ✓ Phase one reveals interfaces and reduces risk. This becomes increasingly important when complexity and risk are high.

6. Use a mix of fixed price, unit prices and reimbursable prices

- **Uncertainty:** ✓ Unit rates and reimbursable fit variable quantities and investigative tasks when there is no clear scope. Use more flexible pricing when uncertainty is higher.
- **Complexity:** ✓ When complexity is high flexible pricing can help contractors to be interested in the project and lowers tender cost because contractors do not have to give out final pricing in early stage.
- **Repeatability:** ▲ Fixed price is efficient when quantities are fully stable this can be the case when a series of similar objects have already been completed, while unit rates help when tasks repeat but quantities vary per site.

7. Invest in client side technical expertise

- **Always applicable*:** More technical expertise from the client side can always benefit project outcome with greater collaboration and joint decision making.
- **Uncertainty:** ✓ Capability to retain or transfer the right risks and to make timely design choices together with contractor.
- **Complexity:** ✓ Technical expertise can help joint decision making about complex projects.
- **O&M importance:** ✓ Stronger owner input improves life cycle choices and handover quality.

8. Stimulate long term collaboration for example through framework agreements

- **Repeatability:** ✓ Framework agreements become more beneficial when repeatability and quantity of object is high.
- **Scarce market capacity:** ✓ Framework agreements lower tender cost and time increasing the effective work of contractors.

9. Make a realistic plan with a consistent deal flow

- **Always applicable*:** A predictable planning and deal flow is always benefic al for contractors and asset managers to base their investments and actions on.
- **Scarce market capacity:** ✓ consistent deal flow allows investment and optimal use of capacity by contractors this is always important but becomes increasingly important when market capacity is scarce.

10. Use incentives to align client and contractor goals

- **Always applicable*:** Effect depends on what outcomes are targeted in the given context. This can be on LCC or on efficiency based on the goals and context of the project. But this can always be applied.

11. Use contractor expertise early, even in a pre competitive stage

- **Always applicable*:** Using contractors early on can always be beneficial.
- **Uncertainty:** ✓ Improves build ability and risk realism before pricing.
- **Complexity:** ✓ Market input on how to tender the project and which complexities can be reduced by public client.
- **Repeatability:** ✓ Advice on bundle size and sequence to maximise flow and learning.

- **Scarce market capacity:** ✓ Reveals what the market can credibly deliver in the window and what is needed from client to have a successful tender and project.

12. Promote open communication and transparency around risks and opportunities

- **Uncertainty:** ✓ Surfaces unknowns early and reduces defensive pricing.
- **Complexity:** ✓ Supports joint indentification of risks and solutionss.
- **O&M importance:** ✓ Clarifies trade offs that affect life cycle outcomes.

13. Focus on renewing infrastructure and avoid too many "nice to haves"

- **Complexity:** ▲ A tight focus reduces coordination load, yet do not exclude network upgrades that deliver clear value within the same access window.
- **Repeatability:** ✓ Core focus supports standard methods and series routines.
- **Scarce market capacity:** ✓ Frees scarce people and resources for value adding work.

14. Bundle projects so contractors can use their resources efficiently

- **Complexity:** ✗ unique high risk assets in one bundle inflate risk allowances and deter bidders.
- **Repeatability:** ✓ Similar objects enable scale and learning.
- **Scarce market capacity:** ✓ bundling lowers transaction and tender cost and lowers idle time for scarce resources and personnel which increase output.

15. Promote consistent teams across projects for clients as well as contractors

- **Always applicable*:** Consistent teams can speciallice in a certain type of assets and become experts when keeping the teams consistent this can benefit project outcome regardles of context.
- **Complexity:** ✓ Learning becomes more valuable for complex projects when they are similar.
- **Scarce market capacity:** ✓ Higher output with the same resources is important when capacity is scarce.

16. Focus client attention more on strategic programme management

- **Repeatability** ✓ When programmes become large because of high repeatability and quantity. Steering on strategic management can help create a ecosystem of suppliers and partners that can jointly learn and work together to optimise efficiency across different project bundles.
- **Scarce market capacity:** ✓ Active management of scarce people, resources and suppliers. becomes more important when there is more scarcity.

17. Initiate and co develop standardisation and industrialisation with the market

- **Complexity:** ✗ Unique or highly integrated assets require tailored solutions and is difficult to standardise.
- **Repeatability:** ✓ Standard components and prefabrication yield large gains with many similar assets.
- **Scarce market capacity:** ✓ Especially when market capacity is scarce it is important to try and increase productivity and efficiency this can be done by standardisation and industrialisation.

18. Promote standardisation and collaboration across public clients

- **Complexity:** ✗ Unique or highly integrated assets require tailored solutions and is difficult to standardise. Also some objects have sentimental value and should not be standardised.
- **Repeatability:** ✓ Shared standards create scale and reuse across programmes of different clients.

- **Scarce market capacity:** ✓ When market is scarce it is important to make use of each others expertise and try to work together to achieve efficiency gains.

D

Initial Decision making framework

Advice	Uncertainty	Complexity	Repeatability	O&M importance	Scarce market capacity
1. Avoid using private finance for R&R.	✓	✓			
2. If private finance is used, first clarify scope and price.	✓	✓			
3. Give more priority to total LCC from project start.				✓	
4. Promote the use of integrated contracts.		▲	✗	✓	
5. Use phased contracts to jointly reduce risks and unknowns.	✓	✓			
6. Use a mix of fixed price, unit prices and reimbursable prices to balance flexibility and price certainty.	✓	✓	▲		
7. Invest in client side technical expertise.	✓	✓		✓	
8. Stimulate long term collaboration.			✓		✓
9. Make a realistic plan with a consistent deal flow.					✓
10. Use incentives to align client and contractor goals.					✓
11. Use contractor expertise early, even in a pre competitive stage.	✓	✓	✓		✓
12. Promote open communication and transparency around risks and opportunities.	✓	✓		✓	
13. Focus on task of renewing infrastructure.		▲	✓		✓
14. Bundle projects so contractors can use their resources efficiently.		✗	✓		✓
15. Promote consistent teams across projects for clients as well as contractors.		✓			✓
16. Focus client attention more on strategic programme management.			✓		✓
17. Initiate and co-develop standardisation & industrialisation with the market.		✗	✓		✓
18. Promote standardisation and collaboration across public clients.		✗	✓		✓

Table D.1: Initial Decision making framework

E

Expert evaluation protocol (Dutch)

Doel en opzet Dit protocol beschrijft de werkwijze voor het valideren van het decision making framework (DMF) voor R&R: de vijf contextdimensies, de advies–context matrix en de vertaling naar contractkeuzes. Het protocol is bedoeld voor 1-op-1 expertinterviews.

Deelnemers en selectiecriteria

- Profielen: publieke opdrachtgevers (RWS/provincies/gemeenten/waterschappen), opdrachtnemers, adviseurs.
- Rol: Vergeleken met de interviews ligt de focus van de rol van de validatie sessie meer op practische kant van mensen die contracten echt toepassen.
- Ervaring: Vervaning en Renovatie projecten, programmatisch werken/bundelen, DBFM contracten, aanbesteding.
- Onafhankelijkheid: deelnemers waren niet eerder betrokken bij dit onderzoek.

Expert evaluatie protocol

1. **Introductie afstudeeronderzoek**
    - Introductierondje.
    - Toelichting op het afstudeeronderzoek.
    - Uitleg over doel en opzet van de expertevaluatie.
    - Toestemming vragen voor audio-opname van de sessie.
2. **Presenteren en bespreken raamwerk**
    - Toelichting op de Decision Making Framework, vijf contextdimensies, , adviezen en de vertaling naar de drie contractkeuzes.
    - Vragen of de adviezen worden herkend en helder zijn.
    - Vragen of context dimensies helder zijn en/of sprake is van ontbrekende dimensies.
    - Bespreken of het decision making framework aanpassing behoeft.
    - Vragen of de drie contract proposals herkendbaar en realistisch zijn en aanpassing behoeven.
3. **Afsluiting**
    - Samenvatting door de onderzoeker: belangrijkste bevindingen en verbeterpunten volgens deelnemers.
    - Vragen naar aanbevelingen voor toekomstig onderzoek en/of mogelijke pilot/implementatiestappen.
    - Bedanken voor deelname en aangeven hoe en wanneer resultaten worden teruggekoppeld.

F

Gebruiksaanwijzing Decision Making Framework (DMF)

F.1. Doel en doelgroep

Deze bijlage helpt publieke opdrachtgevers en aannemers het Decision Making Framework (DMF) eenvoudig toe te passen voor Vervanging en Renovatie (V&R).[1] Het DMF koppelt *context* aan *adviezen* en vertaalt deze naar *contract- en samenwerkingskeuzes*. Een uitgebreide rubric en toelichting op de symbolen staat in Appendix C van het hoofdrapport.

F.2. Stappenplan in het kort

1. **Verduidelijk doelen.** Bevestig de strategische projectdoelen en bepaal of en hoe bundeling van objecten logisch is.

2. **Profileer de context.** Scoor het project op de vijf dimensies met behulp van de rubric uit Appendix C (laag–middel–hoog).

3. **Selecteer en prioriteer adviezen.** Adviezen met ✓ bij de gescoorde condities vormen de basis. Markeer ✗ als risico of aandachtspunt en noteer ▲ voor projectspecifieke uitwerking.

4. **Vertaal naar contractkeuzes.** Leg de gekozen adviezen naast de vier aanbestedingscomponenten: *Realisatie vorm*, *Belongings systeem*, *selectieprocedure* en *samenwerkingsmodel*.

F.3. Kern uit Appendix C (Nederlands)

Symbolen en betekenis

- ✓ **Positief**: het advies wordt waardevoller naarmate de betreffende contextdimensie hoger scoort.
- ✗ **Negatief**: het advies kan contraproductief zijn of vraagt extra aandacht bij een hoge score.
- ▲ **Contextafhankelijk**: het netto effect hangt af van projectspecifieke keuzes of randvoorwaarden.

Rubric voor het scoren van de vijf dimensies

Onzekerheid *Laag*: scope en toestand zijn in beeld, vergunningen grotendeels rond, beperkt restonderzoek.
Middel: enkele onbekenden, aanvullende onderzoeken en afstemming nodig.
Hoog: toestand of scope grotendeels onbekend, afhankelijkheid van derden, hoge kans op wijzigingen.

[1] In de hoofdtekst wordt vaak R&R gebruikt. In deze bijlage hanteren we V&R als Nederlandse term.

Complexiteit *Laag*: enkelvoudig object, weinig raakvlakken en hinder.
Middel: meerdere disciplines, enkele afhankelijkheden en omgevingsbeperkingen.
Hoog: veel disciplines met sterke interfacing, faseringsdruk en grote omgevingsimpact.

Herhaalbaarheid *Laag*: uniek maatwerk.
Middel: deels te standaardiseren, beperkt aantal vergelijkbare objecten.
Hoog: serie met beperkte variatie en duidelijke leereffecten, standaarddetails mogelijk.

Belang van O&M *Laag*: weinig harde prestatie of beschikbaarheidseisen.
Middel: enkele prestatie en onderhoudseisen die sturen op kwaliteit.
Hoog: hoge beschikbaarheid, veiligheid en lifecycle prestaties, LCC weegt zwaar.

Schaarse Marktcapaciteit *Laag*: voldoende capaciteit en concurrentie.
Middel: tekorten in segmenten of regio's.
Hoog: kritieke disciplines schaars, voorspelbare pijplijn is essentieel.

F.4. DMF in het Nederlands (advies × context)

Op de volgende pagina in Tabel F.1 is de Nederlandse versie van het DMF gegeven.

Advies	Onzekerheid	Complexiteit	Herhaalbaarheid	Belang van O&M	Marktcapaciteit
1. Vermijd private financiering voor V&R.	✓	✓			
2. Als private financiering wordt gebruikt, verduidelijk eerst scope en prijs.	✓	✓			
3. Geef vanaf de start prioriteit aan totale LCC.*				✓	✓
4. Maak gebruik van geïntegreerde contracten.		▲	✗	✓	
5. Gebruik gefaseerde contracten om gezamenlijk risico's en onbekenden te reduceren.	✓	✓			
6. Balans: mix vaste prijs, eenheidsprijzen en vergoedbare posten.	✓	✓	▲		
7. Investeer in technische expertise aan opdrachtgeverszijde.*	✓	✓		✓	
8. Stimuleer langdurige samenwerking.			✓		✓
9. Maak een realistische planning met voorspelbare pijplijn.*					✓
10. Gebruik prikkels om doelen opdrachtgever en aannemer af te stemmen.*					
11. Gebruik markt-expertise vroegtijdig, desnoods precompetitief.*	✓	✓	✓		✓
12. Bevorder open communicatie en transparantie over risico's en kansen.	✓	✓		✓	
13. Houd de vernieuwingstaak centraal.		▲	✓		✓
14. Bundel projecten zodat capaciteit efficiënt wordt ingezet.		✗	✓		✓
15. Stimuleer consistente teams bij opdrachtgever en aannemer.*		✓			✓
16. Richt opdrachtgever meer op strategisch programmamanagement.			✓		✓
17. Start en ontwikkel standaardisatie & industrialisatie met de markt.		✗	✓		✓
18. Stimuleer standaardisatie en samenwerking tussen publieke opdrachtgevers.		✗	✓		✓

Legenda: ✓= positief ▲= contextafhankelijk ✗= negatief * = altijd toepasbaar.

Table F.1: Definitieve Decision Making Framework (Nederlandse versie)

F.5. Van advies naar keuzes: keuzekaart voor de opdrachtgever

Deze paragraaf helpt om, gegeven de contextscores en de geselecteerde DMF-adviezen, expliciet te maken *welke* keuzes de opdrachtgever neemt en *waarom*. Het doel is transparantie in de besluitvorming, om van context naar adviezen naar uiteindelijk contract en samenwerkings vorm te gaan. Hieronder een aantal overwegingen die betrekking hebben op de adviezen uit het DMF, om naar een contract vorm te gaan. Ze zijn gestructureerd volgens de vier contract componenten Realisatie vorm, Belonings systeem, Selectie procedure en het Samenwerkingsmodel.

Realisatie vorm

- **Integratiegraad**. Welke mate van integratie van ontwerp, bouw en onderhoud past bij de contextscores en de geselecteerde adviezen (gelinkt aan adviezen: 3 en 4.)
- **Fasering**. Is een gefaseerde aanpak nodig gegeven onzekerheid en complexiteit? Waar liggen de beslismomenten en welke informatie is nodig om door te gaan? (gelinkt aan advies 5.)
- **Bundeling**. Welke bundellogica is passend (objecttype, regio, tijdvenster) en hoe draagt dit bij aan leereffecten en voorspelbaarheid voor de markt? (gelinkt aan advies: 14)
- **Onderhoudsrol**. Wat is de gewenste rol van onderhoud in de scope en hoe wordt dit verbonden aan prestaties over de levensduur? (gelinkt aan adviezen: 3 en 10)

Belongings systeem

- **Prijsmechanismen**. Welke mix van vaste prijs, eenheidsprijzen en vergoedbare posten past bij de verdeling van onzekerheid en beïnvloedbaarheid van risico's? (gelinkt aan advies 6.)
- **Prestatieprikkels**. Welke prestatie-indicatoren zijn echt sturend (beschikbaarheid, veiligheid, hinder, energie, levensduur) en hoe worden zij gemeten en geverifieerd? (gelinkt aan advies: 10)
- **LCC-sturing**. Hoe worden levenscycluskosten zichtbaar en gedeeld, zodat keuzes met lagere LCC ook aantrekkelijk zijn voor de opdrachtnemer? (gelinkt aan adviezen: 3 en 12.)

Selectieprocedure

- **Waardeweging**. Welke kwaliteitsaspecten wegen mee naast prijs en waarom? Denk aan aanpak voor LCC, hinderbeperking, plan voor pijplijn, teamcontinuïteit en leervermogen. (gelinkt aan adviezen: 3 en 15.)
- **Interactiegraad**. Welke vorm van interactie is nodig om risico's en onbekenden te reduceren voordat prijzen hard worden? Denk aan marktconsultatie, dialoog of pre competitieve verkenning. (gelinkt aan advies: 11.)

Samenwerkingsmodel

- **Governance en rollen**. Hoe is de besluitvorming ingericht, welke rollen en bevoegdheden horen daarbij en hoe worden conflicten opgeschaald? (gelinkt aan adviezen: 7 en 12.)
- **Transparantie en informatie**. Welke gegevens zijn open, hoe wordt de gezamenlijke risicolog gevoerd en hoe verloopt rapportage over kansen en risico's? (gelinkt aan advies: 12.)
- **Continuïteit en leren**. Hoe borg je consistente teams over projecten en hoe worden standaarden en lessen vastgelegd en toegepast? (gelinkt aan adviezen: 8 en 15.)