Circular design strategies in procurement: A comparative case study in infrastructure and building construction

BSc Thesis

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Abstract

The Netherlands, due to resource availability and sustainability concerns, there are national aims to shift towards a circular economy by 2050. Because of this, circular designs strategies are increasingly prevalent in the construction sector. This study, conducted with Hegeman Bouw&Infra, a construction firm specialising in circular and sustainable solutions, addresses the integration of circular strategies in contemporary tendering procedures. The circular strategies explored are based on CB23's framework including designing for prevention, quality and maintenance, adaptability, dissassembly and re-use, with re-used materials, recycled materials and renewable materials. The research framework guides the analysis of two specific cases, one in building construction and the other in infrastructure. The methodology includes conducting interviews of relevant individuals as well as a document analysis of the various documents in the tendering phase, including client criteria, contractor bids and the clients verdict. By systematically comparing the results of interviews and document analysis against the seven circular strategies, a comparison can be made on the implementation and articulation of said strategies between the client and the stakeholder. By outlining similarities and differences between the strategy approaches, the cases can be compared against one another to identify where the largest differences emerge on client and contractor articulation and emphasis of certain strategies. By noting the most significant differences, specifically in adaptability and re-use, it is then discussed how these differences emerged in the cases. It provides a foundational understanding on how theoretical universal circular construction practices may need different approaches in practice per sub-sector. Future research should focus on expanding the cases to identify whether these findings can be extrapolated for the industry as a whole, or whether it was primarily relevant for the context of the two cases.

Contents

1 Introduction

1.1 Background

The construction sector is required to significantly adapt to contemporary challenges of resource depletion, waste minimization, and climate change. It is well recognized that the construction sector is one of the largest polluters globally,Hussin et al., 2013. This is also true in the Netherlands, where approximately 35% of the total emissions nationally are attributed to construction, pinpointing the sector as a key area for improving sustainability (Platform CB'23, 2023).

There are many papers that explore the necessity of sustainable thinking in construction such as Hussin et al., 2013, Pitt et al., 2009, and the book Halliday, 2008. These papers primarily advocate for green construction and integration with nature, zero waste designs, re-use, and recycling. These well-cited papers from 2008-2013 however, do not make explicit note of circularity, indicating its recent role in the sustainability paradigm (as of 2025).

To define circularity, Kirchherr et al., 2017 compiling over 114 sources came to define the circular economy as: "**A circular economy describes an economic system that is restorative and regenerative by design, and which aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles.**"

Circularity, while distinct, overlaps with sustainability in definition. However, the clarity of the boundary is not firmly established. For example Walker et al., 2022 conducted surveys from Dutch and Italian firms on the difference and connection between circularity and sustainability. The paper notes that distinguishing the two concepts in daily operations is synthetic and futile to some respondents. However, the general practical consensus is that sustainability is an overarching concept while the circular economy is a set of practices to achieve the said concept.

According to Blomsma and Brennan, 2017, the circular economy model emerged from various waste management strategies focused on resource conservation. As economies become more environmentally conscious, circularity developed as its own umbrella concept to include strategies that help facilitate resource security. As discourse around circularity increased, various perspectives, variations, and models developed, diverging from one another. For example, previously noted Kirchherr et al., 2017 identifies 114 definitions of what a circular economy is, and what falls under it. According to Ghisellini et al., 2016, circularity is continuing to trend into becoming the new standard of waste management in many large and/or developed economies such as China, Japan, and the European Union. Circularity does have key distinctions from general sustainability, as outlined in Geissdoerfer et al., 2017. Generally, circularity is scoped within the realm of material waste management and has primarily environmental and economic goals, while sustainability is far more encompassing on concepts of endurance, including social sustainability and other immaterial factors. Geissdoerfer's paper also identifies how various researchers and organizations maintain contrasting perspectives on circularity's role in sustainability, with the range including those who consider it conditional for sustainability, from those who think it is beneficial to sustainability, to those who consider it a trading off with other sustainability factors.

Due to the lack of focus on social sustainability, critics of the circular economy, such as those gathered by Corvellec et al., 2022, criticize its unclear contribution to areas of sustainability outside of waste management. The paper also notes the "definitional quagmire" of circularity, due to the wide range of definitions for a singular concept.

One of these defining groups is the CB23. CB23 is a national platform that makes agreements between government, academic, and industrial organisations on defining circularity in the construction sector. It identifies seven unique circular design strategies to improve circularity specifically within the construction sector. Although many other frameworks are available, such as the aforementioned (Kirchherr et al., 2017), Circular building 2023 was chosen because it matches the scope and context of the research paper (explored in Chapter 2).

Parallel to the circularization of the economy and circular design, in recent years, major changes have occurred to the tendering and designing process in the construction sector. Historically, most tenders were bid-build contracts, where the client releases a design, and contractors compete to make the best construction plan to implement the said design cost-effectively. This meant that most of the creative process was in the hands of the client, while the contractor was focused on fulfilling that vision as efficiently and cost-effectively as possible. This model of tendering is slowly being replaced with a two-stage procedure. In the first stage, contractors are selected based on preliminary designs and qualifications. Afterward, the contractor collaborates with the client on finalising designs and pricing (Lingegård, Havenvid, and Eriksson, 2021). This approach fosters early contractor involvement, making contractors take the initiative in conceptualizing, which increases their role in circular and sustainable design. Another change is the increase in diverse criteria for contract procurement, besides pricing, sustainability, circularity, innovation, social value, and other factors. Through criteria percentage ratios or criteria discounting, contractors are provided multiple avenues to create the desired design (van Berkel and Schotanus, 2021). This change is important for the research scope of this thesis, which aims to investigate the dynamics between contractors and clients on circularity in this new tendering model (further explored in Chapter 2).

1.2 Research Scope

This research compares two tendering cases, one in infrastructure and the other in building construction. Both cases follow a unique organizational process that is similar to two-stage tendering (elaborated in Chapter 2) with an emphasis on circularity. The research is motivated by and done in collaboration with Hegeman Bouw & Infra, a construction firm specializing in both building construction and infrastructure, especially procurements emphasizing sustainability and circularity.

Initially, Hegeman Bouw&Infra was curious about how circular strategies can differ in building and infrastructure to explore whether different approaches need to be taken for the two subsectors. With the broad scope of such a question, it was narrowed down to focus on two cases. One case was a successful procurement in building construction specifically schools in the Municipality of Amsterdam, and the other a non-winning bid in infrastructure in the Province of Overijssel, both of which were foundationally built on the same design principles. By comparing the two cases, differences in the applicability of their set of circular design strategies can be explored.

The exploration of how sustainable goals impact tendering processes is well explored in the literature. For example, Dutch solutions to integrate circularity in tendering relative to other nations are explored in (Lingegård, Olsson, et al., 2021). The paper concludes that Dutch infrastructure project tenders are 'translators' of national policy, meaning that their clients have goals aligned with those set out by higher governing bodies. It also explains the Dutch solution to including carbon-related factors through discounting, which is common for factoring in non-cost-based features. However, the paper generally focuses on carbon emissions calculating and not circular strategies. Additionally its focus on the Netherlands (NL) only includes 1 interview relative to 3, 6, 8, and 17 interviews done for other countries. Although this provides important context on the nature of sustainable tendering in Europe, more exploration of specifically circular tendering in the Dutch national context can be done.

Another paper (Eriksson et al., 2019) explores how collaborative procurement in infrastructure can drive improvements in collaboration. A key finding is that procurement strategies that engage contractors earlier in the design phase have a higher potential for innovation. The paper, focusing on Dutch and Swedish cases provides relevant geographical-contextual insights on how early contractor involvement drives innovation. The context of what entails innovation however is incredibly broad in scope, with the innovation analysis being done in the context of procurement for sustainable innovation from a Swedish research initiative. This makes the research of this paper lack definitive value for Hegeman's Bouw & Infra's cases for two interconnected reasons. Firstly, 'innovation' is defined broadly under sustainability rather than focusing on circularity, while the company seeks to explore circular-specific cases. Secondly, the research initiative is of Swedish origin, which underemphasises the level of importance of circularity needed for the Dutch context. This is because the Dutch national policy explicitly aims to achieve full circularity by 2050 Rijksoverheid, 2023 and the previous papers (Lingegård, Olsson, et al., 2021) indicate that Dutch clients are translators of the national policy. Because of this, it is necessary for the company to delve into further research that recognises the necessity of Dutch tenders to not just be sustainable but specifically circular.

Lastly, the paper (Lingegård, Havenvid, and Eriksson, 2021) specifically explores circular procurements in infrastructure through integrated contracts, significant to Hegeman Bouw&Infra's context as their specific research question explores this topic. It identifies that procurements where the contractor is taken in for all phases including designing, building, and maintaining are most effective for achieving circular public procurement. It identifies challenges to achieving this including a traditional organizational structure that does not effectively facilitate long-term contracts, ineffective cost estimations, and a lack of knowledge. The paper provides valuable insights on how to operate a long-term circular procurement project, however, the bulk of the findings and recommendations are targeted at clients rather than contractors. For Hegeman Bouw&Infra, research is needed that allows contractors to navigate these challenges in circular infrastructure procurement on their own initiative.

For the research scope, precisely two cases will be looked at, one in infrastructure and the other in building construction. Circular design principles related to these two sub-sectors will be explored on the scale of products and projects. Wider circularity principles on the macro scale fall beyond the scope. Additionally, only the tendering process will be looked at, including the tender invitation, design bid, and selection. Further detailed designing, construction, and maintenance are beyond the scope of the paper.

The research strives to explore circular interpretations in a national context as well as provide tangible solutions for calibrating client-contractor understandings of circularity. By exploring how different organizations and individuals identify and emphasize certain aspects of circularity, a clearer view can be made of how circularity is discussed in practice within the Dutch context and the context of sub-sector work cultures of infra and building construction. These findings can provide insights into how sub-sector differences can necessitate a different approach to circular strategies within their respective contexts. The implication of the research can explore whether 'construction' is too broad of a sector to operate with the same approach to circularity for its sub-sectors. It also provides insights into how diverse or unified the perspectives on circular strategies are between Dutch stakeholders.

1.3 Research Questions

Aiming to identify how to effectively match tender requests over the two sub-sectors, the research question is as follows:

"To what extent do Hegeman's circular design bids match the tender request between building and infrastructure."

To answer this question, the study aims to answer the following sub-questions throughout the course of the research:

Q1: How do the circular design strategies of building construction (case 1) contrast and complement one another between client and contractor stakeholders?

Q2: How do circular design strategies of the infrastructure building project (case 2) contrast and complement one another between client and contractor stakeholders?

Q3: How do the circular strategies provided by contractors compare between the two cases

Q4: How do the circular strategies provided by Hegeman Bouw&Infra compare between the two cases

When comparing the results to one another, these sub-questions allow for a verdict on the primary research question by comparing the sub-questions indicated in a matrix on chapter 6.

1.4 Report Structure

This report explores two case studies in tendering for projects that require circularity within two different sub-sectors of construction, buildings, and infrastructure. The report flows as follows: the current chapter introduces the general background of the state of construction contract procurement and contemporary circular economy/design ambitions, then provides reasoning for the research as well as the research question and sub-questions. Chapter 2 provides the theoretical background, explaining the contemporary tendering process in construction and the models of the two cases. This is important as both procurement cases are based on relatively new approaches, the "Innovatiepartnerschap" (Innovation Partnership) and the "Bouwteam" (construction design team) for building construction and infrastructure respectively. The primary purpose of the section is to identify, explain, and justify the most important documents for document analysis, as well as the major stakeholders for interviews. The second part of the theoretical background explains various circular design principles, to allow for clear defining and delineation of design principles, which will be key in comparing and contrasting document & stakeholder insights. Chapter 3 explores the research methodology, presenting the steps of research, and detailing the processes for interviews and document analysis. Chapters 4 & 5 cover the two cases respectively, going into detail about their background and contextual differences. Afterwards, the presence of each of the design strategies is explored based on the interviews and documents. Chapter 6 brings everything together by combining and comparing the two cases, and comparing the degree to which client-contractor perspectives come together and contrast. This will primarily be a qualitative assessment, but the quantitative results are provided (when applicable) for contextualization. Chapter 7 will discuss these results and key findings and interpret them, followed by an evaluation of limitations to this study and further recommendations. Chapter 8 concludes the report, summarizing the outcomes.

2 Theoretical Background

In this chapter, the general theory that is important to understand contextually is explored. Starting with the tendering process, to provide a justification for the chosen documents to analyse as well as which stakeholders come into play. The focus is limited to the scope of the two cases, one of which is a construction design team contract while the other is an innovation partnership. After explaining these contracts in literature as well as in practice, the text guides through the relevant stages of procurement and which stakeholders & documents are generally involved. Afterwards, the relevant circular design principles that will be compared in the cases are outlined and described. First, a framework selection is justified and compared with alternative choices. Then those of the CB23, the seven circular design principles, are stated, their practical implications, and examples of use.

2.1 Construction Design Teams and Innovation Partnerships

In recent years, there has been an increase in tenders pushing contractor involvement further forward in the construction development process into the design phase (Molenaar et al., 1999). While conceptualized at the end of the 20th century, it has steadily grown into the dominant form of contract procurement in many economies and plays a leading role in debates around effective procurement strategies in construction circular design (Lingegård, Havenvid, and Eriksson, 2021). By 2017, a study showed that design-build contracts outperformed traditional contracts on all quantitative metrics Sullivan et al., 2017. With the wide-scale adoption of design-build, a variation emerged locally in the Netherlands known as the "Bouwteam" (Construction design team), which evolved out of design-build but has its own key characteristics.

The key difference between a building design team and a design-build bid is that in the latter the client places all designing and building responsibilities on the contractor, and selects a contractor based on their offer. In building design teams designing and building are done collaboratively between the contractor and the client, making the contractor more involved than traditionally in earlier stages while also making the client more involved in later stages (Nielen, 2010). The consequence of this is that building teams also take into account collaborational and organisational compatibility as well as designing and building elements.

When focusing on the scope of circular design strategies in the tendering phase, this distinction is key to recognising that building design assessments are based both on said design strategies as well as their organisational processes. While the scope remains focused on design strategies and not organisational processes, they both directly influence one another and their respective approaches, which is an essential piece of context to take into account.

The other key procurement approach relevant to the cases is the innovationpartnership. An innovationpartnership is a procurement type developed by the EU to combine research & innovation contracts with procurement itself (**IEPU**). What this means for the construction sector is that first contractors are tendered on their innovation plans and design strategies, and then the contractor implements their innovative concepts on the offered tender(s).

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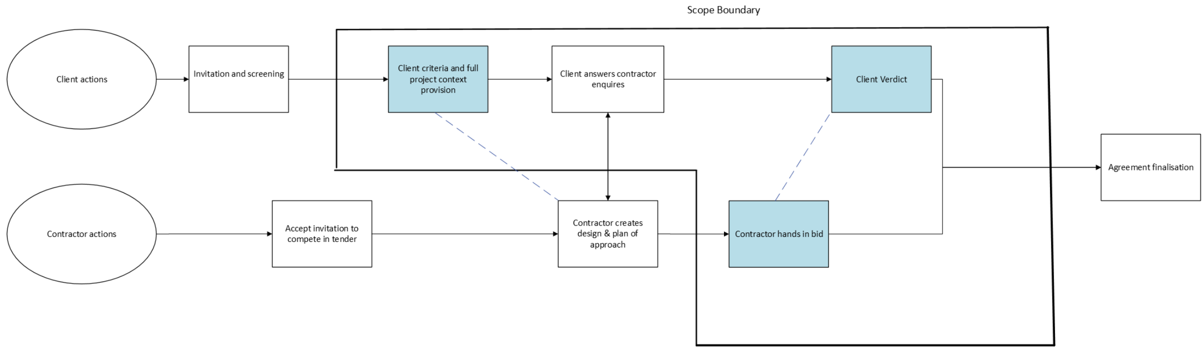

Figure 2.1: tendering process within the scope

The primary differences between a building design team and an innovation partnership are twofold. Firstly, in an innovation partnership, the client takes a similar role to that of a design-build contract, leaving most of the designing and construction processes in the hands of the contractor, while the building design team has deep collaboration throughout. This means building design teams emphasis on collaboration and approach planning, as the client is continuously working together with the contractor consortium. Secondly, in innovation partnerships, the contractor must provide research and development services and then employ them in the designs, while research & development services are not an inherent prerequisite of building construction teams. To summarize, besides design and construction approaches, innovation partnerships also emphasize innovation while building design teams also emphasize collaborative approaches.

When scoping down into the tendering phase, this means that there are differences in necessary content for client criteria, contractor offers and client selection, these content differences (explored in Chapters 4 and 5), however, do not alter the general tendering process.

The figure below shows the major steps of tendering in a typical building design team or innovationpartnership tender, based on the model of (Mulder, 2021) and adjusted/simplified for relevant documentation for the scope.

Figure 2.1 outlines the general case tendering process from the perspective of client and contractor actions. After the initial invitation and screening, the client sends a criteria which is viewed by the contractor (dotted line) to create a tender bid plan. This is followed by an interaction of contractors asking the client questions for further insights and details. Afterwards, the contractor hands in a bid, which is viewed by the client (dotted line connection) which creates a verdict on which contractor(s) they choose to work with. This is followed by agreement finalisation and post-tendering phases. As seen in Figure 3.1 above, the scope is bounded by a set of rules to conduct document analysis and interviews at an appropriate scope.

1. Only stages where documentation is visible either through observation or interaction between client and stakeholders are considered. As the Thesis explores the matching between the bid & request, an essential characteristic of relevant documentation is that it is visible to both stakeholder groups. Therefore many internal processes are not included.
2. Only stages where the contractor is being assessed on circular design principles by the client are included. This excludes steps such as pre-screening primarily based on the qualitative performance of engineering firms. This also excludes agreement finalization and other steps post-client verdicts that remain in procurement, as a competitive assessment is no longer included.

This leaves four stages within the scope outlined in black in figure 2.1. Firstly the client request highlights the criteria, specifically what the client hopes to see in the areas such as circularity. Secondly, the contractor bid is a response to that, offering a design and process that ideally matches the clients' request. Thirdly a response in turn is made by the contractor, giving a verdict on which contractor wins the bid based on how well the designs match the client's request. These three stages are highlighted in blue in Figure 2.1.

While there is also a stage of clients answering questions to the contractor in "notas van inlichtingen" a sort of Q&A, these documents are not included due to their limited focus on circular design strategies and stronger focus on logistics for these cases. Because of this, the stage is not highlighted and not included in the document analysis.

2.2 Framework Selection

Platform CB23 is short for 'Circular Building 2023' and aims to create working agreements between stakeholders in the construction sector to accelerate the goals of reaching a circular economy in the Netherlands by 2050 (Platform CB'23, 2023). On their platform, they describe seven circular design strategies which fall under four groups. The groups are systemic ways of thinking, for which some strategies such as re-use or recycling fall under the same system process in the roadmap, while for example, prevention as one strategy is present in two distinct system processes.

Alternatives to Platform CB23 could include Kirchherr et al., 2017's analysis of 114 definitions, where the circular economy is conceptualised in a broad sense. Although valuable insights, the sector and country-specific focus of CB23 makes it favourable for the scope lens, which focuses on interaction within the construction sector between Dutch stakeholders. Another alternative would be to look at the Dutch circular economy plan as a whole through Rijksoverheid, 2023, however, CB23 is far stronger in operationalizing the goals outlined in the national program making it a preferable framework.

Additionally, platform CB23 is relevant for the context of the two cases. In the building case (case 1), a member of the representative action team is from the municipality of Amsterdam, implying collaboration and use Platform CB'23, 2023. For the other case (case 2), they state in the criteria document (elaborated in Chapter 5) that the Province of Overijssel takes part in national initiatives, of these CB23 is included. Of the initiatives, CB23 is amongst the most recent and is the only one provided with a direct link in the references. This evidence makes a strong case that CB23 is the best circular design strategies framework to assess these two cases against.

2.3 Design Strategies

Below the strategies are listed and defined, including the means and the key considerations provided by CB23.

- **Design for prevention:** the prevention strategy aims to avoid unnecessary new construction, and in cases where this is not possible, designing more efficiently and optimally. The means of achieving this are based on two previous research documents, one done by Witteveen + Bos (Dijcker and Schepers, 2018 and the other by Delft University (Terwel and Crielaard, 2023). The described means include:
  - Reduce the task and investigate existing structures: This includes a diagnostic assessment to decide to potentially not build, clearly determine needs, and find solutions that eliminate the necessity of certain parts. This also includes studying if alternative

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Figure 2.2: Example of multifunctional design, LED railings
"LED Bridge", 2021

solutions can reduce the required material use. It is primarily Terwel and Crielaard, 2023 that provides a clear diagnostic framework for these approaches.

– Another method is to use space and material over time and find alternatives. This includes studying at what exact point in time each element is necessary and potentially phasing implementations based on short, medium, and long-term considerations Dijcker and Schepers, 2018 advocates for this to potentially minimise short-term measures and find 'no regret' solutions. The document also recommends combining functions and looking at whether construction can be used more intensively/multifunctionally, an object-level example provided is replacing a lightpole with LED railings (example shown in figure 2.2).

– The third approach to the strategy is to optimise. This can include optimising the structure as well as the installation system to minimise material use. This can also include optimising the construction method, and specific elements, as well as optimising the material specifications. These optimalisation methods are outliend by Terwel and Crielaard, 2023 specifically within the context of environmental nuisance, but in CB23, this is taken more broadly to include environmental as well as economic and material targets.

Some key considerations when designing for prevention is that it is not an isolated strategy, omitting things that are not needed in the moment can affect the future proof of construction. Integral design is a prerequisite for this approach, as prevention choices can for example affect the lifespan or disassemblage potential.

- **Design for quality and maintenance:** Designing for quality and maintenance focuses on the future value of constructions. This also applies to the upcoming design for adaptability and design for disassembly and reusability strategies. Specifically for quality and maintenance, the goal is to maintain high quality and aesthetics to create value for stakeholders, as well as minimising the cost and burden of maintenance. Means to achieve this include:

  – Aiming for a design to be cherished. By creating a design that provides emotional and aesthetical value, stakeholders are willing to invest in the long term. By building a strong presence and recognisability, stakeholders across generations can value the construction.

  – In Dutch standards, non-residential buildings should last around 50 years, residential 75, and infrastructure 100 years. A key aspect of this is robustness, which is achieved by using high-quality materials and careful detailing.

  - Design constructions that become more beautiful through use and maintenance
  - Primarily focus on long-cycle layers such as the building shell for long-term quality
  - Aiming for the highest possible appreciation from users, providing good functionality such as logical floor plans, accessibility, heights, admission of daylight e.t.c

  A key consideration of this policy is that if frequent changes in the usage or requirements of the construction are to be expected, designing the following design for adaptability should be combined with the design for disassembly and re-usability. CB23 indicates that in these contexts, different lifespans can shift the primary strategy priorities. By integrating social sustainable elements like aiming for cherished design, CB23 mitigates some reservations against circular design outlined in Corvellec et al., 2022 such as a lack of focus on social sustainability.

- **Design for Adaptability:** the aim is to meet various expected future scenarios with different needs and requirements, it is the design's capacity to respond to change. This can be due to for example changes in users, climate patterns, or technical requirements. Adaptability extends lifespan by allowing the design to continuously evolve to new requirements. There is a key difference between technical adaptability and spatio-functional adaptability. Technical adaptability means that constructions can be disassembled, are accessible, and are physically independent, also explored in design for disassembly and re-usability. Spatio-functional adaptability is present if the design can handle changes in functional or spatial requirements, through for example making configurable floor plans or over-dimensioning pillars and pipe-space.

  - Design with future scenarios in mind for construction and changes. This includes a range of approaches including smart design of space and structure to enable different forms of use, including reserving space. Another example is over-dimensioning to allow for other load scenarios, or allowing for further excavation in the area. Additionally for building construction making room for additional installations is also of import.
  - Distinguishing between different construction layers is also important, separating long cycles (structure and shell) and short cycles (instillation, room layout) allows matching between expected technical and functional lifespans.
  - Another tenant is traceable digital documentation that ensures designs remain relevant. Anticipating climate change scenarios such as higher water levels throughout the Netherlands climate adaptability is a significant core tenant.

  Key considerations include noting that the scenario correlates with the aforementioned design for quality and maintenance as well as the upcoming design for disassembly and re-use, the three strategies reinforce each other.

- **Design for disassembly and reuse:** this strategy is a zoom-in on the aim of achieving technical adaptability. The strategy requires materials to be easily separable without damage for the highest quality re-use. It is technically adaptive if connections can be disassembled and parts are accessible and demountable. The strategies are primarily based on those outlined by Van Vliet et al., 2021 and by Ter Heijden and Scheepens, 2023:

  - Design with disassemble connections, Ter Heijden and Scheepens, 2023 creates a framework scoring connections on their disassembly potential. The highest-scoring

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Figure 2.3: Layers of Brand as provided by Dutch Green Building Council

connections include clicking connections, screws, and other dry connections. Low-scoring connections are generally wet connections, but soft connections like sealant are favoured over hard chemical connections such as glue or for example welding pieces together.

- Make sure connections are accessible, less long-lasting elements should be easily reachable by crews to minimise damage to other parts and to maximize ease of access. Van Vliet et al., 2021 for example makes a framework for this, scoring freely accessible elements the highest while scoring elements where accessing causes irreversible damage to the construction as the lowest scoring.
- Avoid unnecessary integration of elements. Avoid elements with different lifespans passing through each other, crossing or intersecting. Avoid hybrid materials whose raw materials cannot be disassembled or organised in separate cycles (such as technical and biological). A key system for this is the stewarts layers of brand. Van Vliet et al., 2021 provides a figure below that effectively communicates how layers of brand work, making each shell independent from one another based on their lifespans. The figure also shows the key importance of making sure elements of different lifespans are not inaccessibility enclosed by elements with a longer lifespan.
- The last tenant is working with a standardised and modular system. This allows for using standardised dimensions that allow project elements to be re-used across projects. A notable example of such a technical framework is Industrial, flexible, and disassemblable (IFD). This example is notable as it was partially founded on the initiative of the Province of Overijssel, which is a key stakeholder in case 2.

Some consideration is that design for disassembly does not create an immediate sustainable impact, but rather, it is an investment in the future potential. Some other considerations are that dissassembleabilty can affect qualitative performance and negatively affect aesthetic elements, meaning a balance has to be made between quality and maintenance. Additionally, elements such as avoiding integrating layers and hybridisation may contradict prevention strategies, as seen in the contradiction between the goals behind Figure 2.2 and Figure 2.3, it is important to prioritise based on context. Lastly, design for disassembly can heavily impact the upcoming mentioned strategies, increasing the supply of re-used construction parts at the expense of high-grade recycling for example.

- **Design with re-used construction parts:** repurpose old elements, repair & refurbish from marketplaces (such as Bruggenbank, hubs, and demolition companies, re-manufacture with re-used parts, and re-purpose existing structures. This can all occur on a design level such as re-using a building to an element level like re-using a concrete column. It should be noted that this policy specifically concerns itself with using re-use materials at the beginning of the project cycle, rather than preparing material for re-usability, which is covered in the previous policy of design for disassembly.

- **Design with secondary raw materials:** aiming to reduce the use of virgin materials, with a preference for high-grade processing such as crushed concrete, asphalt, and recycled steel. This can be either in the form of upcycling (increasing value), recycling at the same quality, or down-cycling at a lower quality. Where Dutch policy such as in the national plan of Rijksoverheid, 2023 from generic circular models such as Kirchherr et al., 2017 is that generic models are generally more accepting of down-cycling. In the Dutch national and sector plan, the aim is to recycle at the highest grade possible to minimise residual waste and down-cycling.
- **Design with renewable materials:** aim to use naturally replenishing materials such as timber, bamboo, and bio-based materials. Means to achieve this include:
  - Use local raw materials, for example, avoid exotic hardwood for construction, additionally avoid non-sustainable suppliers.
  - Separate technical and biological cycles, especially avoid hybridisation between bio-based on fully inorganic materials
  - Match the detailing with biobased materials, besides just implementing bio-based materials, the design's geometry should match the properties of biobased materials to avoid premature design malfunctions. Some important considerations is that using biobased does not necessarily always improve carbon emissions scores. This is especially true when using additional items such as flame retardants, fungicides, insecticides e.t.c on for example wood construction.

Under these seven strategies, the approaches of circular design in construction are covered. By comparing the presence of these strategies in the documents and interviews, comparisons can be made between what is noted and/or emphasised by the client stakeholder compared to the contractor. These strategies are not definitive, and potentially emergent strategies may be worth discussing.

3 Research Methodology

This chapter explains the research methodology. It first presents the research technique and how research is conducted to answer the research questions. It then presents the three main sources of information used in the report: literature review, document analysis, and interviews. It provides justifications, scope, and guidelines for each and how they contribute to the validation of the thesis.

The study uses an exploratory, multi-case study design based on Robert Yin's case study methodology Yin, 2014. A key advantage of this method is that it is rich in contextual analysis. This is important for scenarios where there are limited opportunities for unique data entries (tendering cases) and each case has its unique circumstances that make a controlled environment impossible. It also provides immediate practical insights as it is grounded in real-world scenarios. The scale of the thesis is not appropriate for making generalized remarks about the industry and field as a whole, but by comparing two distinct cases, the reasoning for their respective results can be used to hypothesize for future research on more generalized conclusions. In early-involvement tendering, finances are the primary quantitative assessment, which falls outside the scope of the thesis. Although quantitative goals can be set by clients and contractors, the achievement of said goals is described qualitatively during this early phase. The scope of circular design in the tendering phase is qualitative heavy, making the most common research techniques in engineering, such as experimental, computational, or analytical research designs not suitable. Although the case study by Yin was designed for social sciences, it also lends itself well to comparing designs during the early conceptual phase. Additionally, longitudinal designs are not considered due to the only recent relevancy of circular design in construction (Çimen, 2021). Lastly, (direct and participant) observation techniques were not considered due to the time frame of the thesis.

A key aspect of the case study is triangulation (Noble and Heale, 2019) which combines various sources of data to accompany the literature review to increase the validity. For this, document analysis and interviews were chosen and further justified in their respective sub-chapters. The figure below presents the general structure of the research design.

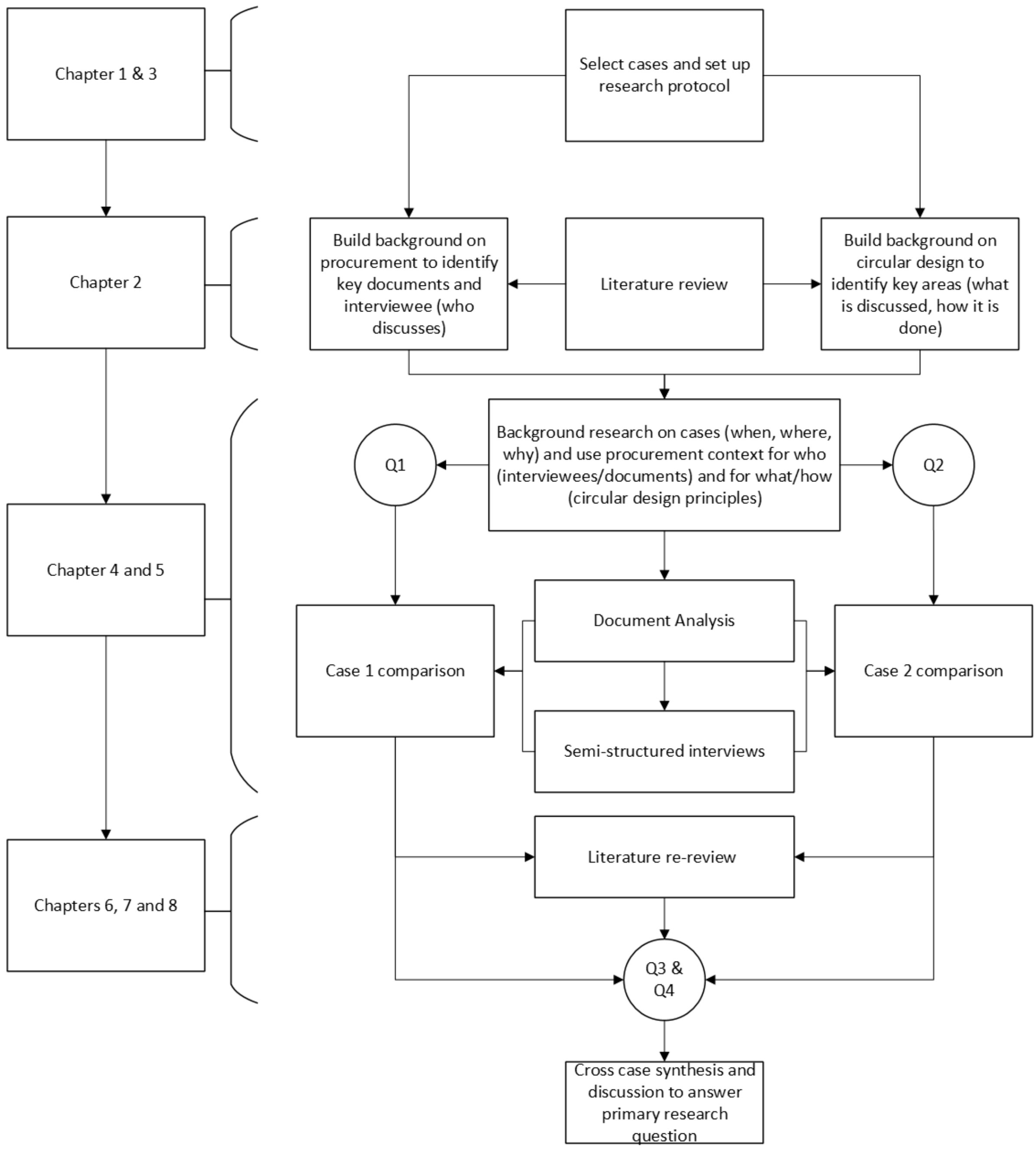

Figure 3.1: Research design process

In the research design, the initiative starts with selecting the cases and scope (chapter 1) and outlining the research protocol (chapter 3). From this, contextual research will be approached. The research focuses on identifying circular design principles to organize a framework for standardizing ideas, discussions, and conversations. This is accompanied by contextual research on the key stakeholders and the key documents by exploring the tendering/procurement process. The chapters rely on the literature review and framework and build the theoretical foundation to dive deep into the two cases. The following chapters, 4 and 5, explore the two cases separately, selecting documents to analyse and interviewees and design principles of chapter 2. Once the case comparisons are complete, the literature is re-reviewed based on findings from the documents and interviews. Lastly, a cross-case synthesis and discussion around the results of Q1 and Q2 are made to then contrast the two cases in Q3, and stakeholder groups in Q4.

Finally, the answer to the primary research question of how circular design bids match between the contractor and client is explained. This can be seen in chapters 6, 7, and 8.

3.1 Document Analysis

A core part of understanding the cases studied is through document analysis. Document analysis is systematic and qualitative and is used to interpret and analyse written material to conclude a topic (Bowen, 2009). In general, limitations of document analysis pertain to availability and biases or limited perspectives. These limitations are mitigated, however, by luckily having full access to documents detailed in the groups below, making availability a non-issue. The full access was provided at the courtesy of Hegeman Bouw& Infra to allow for an open and in-depth analysis. Additionally, the biases and perspectives of the documents are precisely what the case study aims to research; therefore, for the specific context, this is not a limitation but rather a feature. Unfortunately, alternatives such as observation were not considered due to the procurement phases already being passed at the time of research. Additionally, a longitudinal study was not chosen due to the limited timeframe of circular design in construction, especially infrastructure, and the restricted access to documents over a large span of cases.

In terms of document scoping, three document groups are identified, into which documents need to fall to be valid for this document analysis.

- Group 1: Request documents of clients stating the requirements to contractors.
- Group 2: Bid, documents by contractors to clients, usually a series of 1-3 papers by which the client makes a verdict on the winning tender
- Group 3: Verdict, a client text to contractors giving insights and justification on their final ruling.

3.2 Semi-Structured Interviews

A semi-structured interview is a type of interview where a series of questions are prepared for the interviewee while also giving room to go into additional topics and clarification through follow-up questions (Adams, 2015). The advantage of interviews is that they can provide detailed insights into the thought processes of stakeholders in the thesis research that otherwise would not be put or clarified on paper. It was chosen over alternatives such as surveys and questionnaires for two reasons. Firstly, the advantage of high people outreach through surveys and questionnaires was insignificant for the case study due to the limited scope of major stakeholders and decision-makers. Additionally, the room interviews give in-depth questions, elaborations, and clarifications that are essential to get to the root of the research and find out to what extent Hegeman's circular design bids match the tender's circular design perspectives.

The total number of interviewees is seven, with three interviewees for the construction case and four interviewees for the infrastructure case. Of the interviewees in each case, two are from the contractor (Hegeman), one from the construction client, and two from the infrastructure client. For each interviewee, the same set of roughly nine questions are asked by default; these include:

- Introduce yourself and your professional experience (for contextualization, 5 min)
- How did you apply [circular strategy] in the construction/infrastructure of your case project? The design principles are covered for roughly 50 minutes. Their order in the interview can vary based on the flow of the conversation as long as all seven principles are explored within the interview

- Reflection on what were challenges and what could have gone better in their specific case (5-10 min)

Generally, all interviewees receive the same questions. However, conversations can vary based on pivots in follow-up questions or areas of elaboration.

The interviews are then transcribed into summaries of the interviewee's background, their approach to the strategies, and their reflections. These summaries are available in the appendices.

3.3 Qualitative Comparison & Assessment Framework

The last part of the research methodology is bringing everything together in chapter 6. When searching for answers as to why these things occur, a literature review is conducted based on new insights from document analysis and/or interviews. This can, for example, include exploring literature on circular design sub-concepts that fall under one of the seven principles but can be explored in more detail (e.g., material passport for reuse). This literature re-review is primarily explored in the discussion of chapter 7. The discussion of these findings then leads to a conclusion on the findings of the report in chapter 8.

4 Case Study 1: IPS

The Innovationparterschap schoolbouw (IPS) project case is explored in this chapter. Starting with a case background, which contextualizes the nuances of the case and justifies the choice of documents and interviewees. Next, the interviewees and documents are briefly described, outlined, and given a tag for further discussions.

4.1 Case Background

According to the information document of the Municipality, Amsterdam is a rapidly growing city, aiming to build around 70,000 new homes by the end of 2040. It is estimated that around 40 elementary and 10 middle schools need to be built. The IPS was set up to tackle the increasing demand for public services in education which was growing in gap from the sector's capacity. The promise is for at least 9 schools to be built within the IPS project and up to 30, with the potential contractor competing on the best solution to do it in an environmentally, economically, and socially sustainable manner.

Part of IPS is that there are multiple tendering phases. Firstly, companies compete to become part of the general IPS, of this three companies are chosen to go to the next phase. In the following phase, all three companies compete on their designs for each school building individually, essentially going through internal mini-competitions between the companies. The focus will be on the first phase, where companies compete to participate. This is because it shares the most properties with the tendering of the other case, focusing on qualitative ideas, concepts and visions.

In the first phase, an information brochure is presented which outlines all of the client's expectations for deliverables and their contents. Potential contractors must present their vision, plan of approach, and innovative concept. In the vision they explore their big picture plan for how the school construction should look like, and in a concise document, provide a general overview. The plan of approach is a zoom-in document on processes from an organisational management level. The plan of approach can thematically explore circular strategies but is intrinsically about management and organisational strategies. Because of its focus on organisation rather than circular strategy, it is not included in compared documents. The innovative concept document views in on what they are doing new, and has the bulk of content concerning circular strategy.

Based on these three documents, the Municipality sends a verdict that ranks the five finalists from most promising to least promising (of which Hegeman Bouw & Infra was the most promising). This is followed by a brief elaboration on their choice of verdict. This document is important to identify the key bridges between the client's request and the contractor's bid.

Table 4.1: List of documents IPS

Document Tag	Document	Document author	Importance
D1.1	Information brochure	Client	Requirements and context
D1.2	Vision	Contractor	General plan
D1.3	Innovation concept	Contractor	Circular strategies
D1.4	Verdict	Client	Outlines contract winner

Table 4.2: List of Interviewees IPS

Person tag	Organisation	Position	Background
P1.1	Municipality of Amsterdam	Development Manager	Civil engineer
P1.2	Hegeman Bouw & Infra	Tender management	Process engineer
P1.3	Hegeman Bouw & Infra	Design leader IPS	Woodworking construction

4.2 Document Analysis and Interviews

Below is the list of documents and interviewees, as well as their identification tags. To make them identifiable at a glance without excessively re-consulting the table, they are identified as D or P (Document/person) followed by a 1 for case 1. This is then followed by a number for individual identification.

Below the various areas of circular design strategies are discussed, how both the client and the contractor approach them to get insights on the choices made.

4.2.1 Design for prevention

Prevention generally has two different operating levels. One is on 'refuse' or preventing unnecessary projects as a whole. **The tender manager (P1.2)** and **the design manager (P1.3)** did not take this strategy into consideration, as usually, once a construction plan enters the procurement phase this has already been 'crossed out', additionally, it is firmly against the stakeholder interests of these interviewees as they work for the construction company. **The development manager (P1.1)** Mentions that this approach to prevention was not taken due to the municipal context, anticipated large population growth in Amsterdam, retrofitting buildings or crowding existing schools was not deemed feasible. This means that prevention on a project level did not play a strong role in the procurement process, on an element optimization level, however, there is significant presence, which is primarily outlined in documents.

In **the information brochure (D1.1)**, Optimization is mentioned as a potential method to speed up processes and reduce resource use. Beyond two explicit mentions, it is also implied with sustainability goals.

In documents **vision (D1.2)** and **innovation concept (D1.3)**, Optimisation is mentioned on many occasions. This can refer to optimization of mainframe structures, modular components, and the system process. Generally, optimisation is not approached as its own strategy, but rather as an attachment or complement to other strategies. For example, the grids are optimised for adaptability, or the walls are optimised for detachability.

To conclude, neither the contractor nor the client approached prevention on a project level, and no comments were made on the topic in the documentation. For component optimisation, the client does not explicitly request it. The contractor embeds it throughout the design process and other strategies instead of approaching it as its own phase.

4.2.2 Design for quality and maintenance

In IPS, both technical and functional lifespans are taken into consideration. **The design manager (P1.3)** explains that elements are looked at at different lifespan layers, where elements such as the mainframe aim to have lifespans of over 120 years, while walls for example are designed for a twenty-year lifespan. There is a big contrast in commitment to lifespan quality for different elements, for example, the interviewee notes that concrete columns are deliberately over-designed to handle the extra weight. This allows for a longer technical lifespan and ties in with adaptability by continuing to meet technical requirements if, for example, more floors were to be added. Items such as walls and furniture, for example, are instead made to be rapidly swappable and replaceable, avoiding fixed joints as much as possible. The municipal **development manager (P1.1)**, closely associates the concept with flexibility, including detachability, which also aligns with the contractor approach. CB23's own framework notes that anticipating changing technical and spatio-functional requirements, adaptability, and disassembly should be combined as the main quality approach, and the interviewees seem to be in agreement on this.

In **the information brochure (D1.1)**, long-term quality and value retention is important. The municipality emphasises social sustainability, wanting a design that is not just functional, but also represents the identity of the school. Inclusive and context-sensitive designs are important to the municipality. On quality and enduring quality retention, social sustainability is highly emphasised (over for example technical endurance).

In **the innovation concept (D1.3)**, the strategy to maintain a long social lifespan is to create a design where the user is central. By making space for a wide range of modules, each school can adjust their designs to best personalise for their contextual circumstances. Additionally, there is a commitment to comfort in the buildings, aiming for as much fresh air, daylight, and temperature balance as possible to make it user-friendly. By maximising these qualities, the school builds its social value and in turn its value retention.

To conclude the focus on quality and maintenance is generally encompassed by adaptable and disassemblable designs. Under the scope of quality specifically, however, from a client perspective, social requirements are emphasised over technical ones. In turn, the contractor approaches quality differently at various element levels, for example, walls having a 20-year lifespan while the mainframe has a 120-year construction. With the contractor focusing on maximising air quality, natural light, and temperature control, they create a high-quality and socially comfortable design that matches client needs.

4.2.3 Design for adaptability

Adaptability plays a key role in IPS and can be approached from a spatio-functional perspective and a technical perspective. **the tender manager (P1.2)** and **the design manager (P1.3)** almost always refer to adaptability in reference to modularity. With modularity meaning the capability to detach, expand, and move construction units, parts of the school design can be adapted based on technical, functional, and aesthetic needs. For both **the tender manager (P1.2)** and **the design manager (P1.3)** questions on quality and maintenance, adaptability, and then on disassembly and re-use were often interpreted as 'repeat questions', with modularity holding the central focus of all three strategies. For **the development manager (P1.1)**, adaptability on an individual school project level focuses also on functional flexibility and evolution. The interviewee also expands adaptability to a general project level of IPS. By having three winning contractors, the IPS tendering process can undergo a form of natural selection based on which innovative concepts can best adapt to changes in circumstances such as school specifications, supplier availability, and new technologies. According to the interviewee, the concepts should not just be innovative but be able to continuously innovate within the framework. In essence, the framework does not just need to be able to deliver a wide portfolio of adaptable designs based on context but should be intrinsically adaptable framework in itself.

Document **The information brochure (D1.1)** stresses the importance of this, flexibility is mentioned over 26 times and is one of the three key criteria alongside sustainable and qualitative of high value. Flexibility can take many forms, of those suggested in the document include:

- Flexible a range of educational system concepts
- Flexible to a range of student demographics
- Diverse range of sustainability ambitions
- Flexible to various energy systems, e.g no mandatory natural gas
- Flexible for geospatial context (different locations)
- Flexible for modification
- Compartmentalisable
- Re-useability of construction for other functions such as offices or homes.

In the document **the innovation concept (D1.3)**, the contractor captures many of these points through their modular design framework. For example, they set the user central, by creating as many as possible customisation modules aiming to limit restrictions to dimensions and not material/other factors, this captures social context-sensitivity such as geospatial and educational systems. In flexibility, they also commit to minimal necessary installations, and when possible integrate installations with the natural environment such as maximising natural light use. Lastly, the modular wall system allows for efficient modification and compartmentalisation, providing clear potential for functional re-usability. What is significant is that the contractor's primary commitment is to work on a uniform grid, however, it allows elements to be implemented in a variety of forms for example walls of wood, brick, and tiles. By avoiding narrowing the material use too much, the potential for adaptable designing is increased.

In **the verdict (D1.4)** the client complements the contractor's flexible and adaptive designs. Notably it goes further to complement the room for 'continuous innovation', not just the adaptability of the individual schools, but also the adaptability of the framework itself.

To conclude, for the contractor, the concepts of adaptability and modularity are deeply interlinked. This pays off well as the points the client lists as necessary points of flexibility work well with a modular system. The client also appreciates that the modular system shows flexibility and adaptability to continuous changes, showing adaptability on a multi-project level.

4.2.4 Design for disassembly and re-use

Throughout interviews, disassembly and reuse are generally interchangeable with modularity, as modularity is regarded as a commitment to disassembly and reuse on a larger systemic scale. **the tender manager (P1.2)** and **the design manager (P1.3)** both verify the contractor's commitment to modularity as a major circular strategy, showing that by using standardised dimensions schools can easily be constructed modularly without losing context sensitivity. **P1.3** States: "Everything we do is based on disassembly and adjustability", stressing the importance of this strategy in their IPS approach. The client interviewee **the development manager (P1.1)** also discusses in depth the disadvantages of the construction sector's case-by-case design status quo and outlines that the construction sector could benefit from the manufacturing sector's assembly line style approach.

In **the information brochure (D1.1)**, the document mentions over 25 times the term 'flexible'. 'Flexible' in this regard mainly refers to both spatio-functional and technical adaptability.

Many of the flexible criteria, however, can be approached from the angle of modularity, such as adjustability and compartmentalisation.

The contractor firmly takes the modular approach in **the vision (D1.2)** and **the innovation concept (D1.3)**. Their primary innovative concept is to work on a standard grid, and then apply pre-designed elements to said grid to build schools that have interchangeable components with one another. The modular design includes not just structural elements such as walls, but also installation elements such as water and electricity. A core part of the modular design is that it makes a dimensional commitment, but allows for flexibility in materials (as outlined in discussion on recycled and renewable materials).

In **the verdict (D1.4)** they strongly complement the modular design approach, stressing its well-thought-out and detailed planning.

In conclusion, the client does not explicitly push for modularity as a policy, but the contractor chooses it as one of its primary approaches. This is well received by the client, which agrees with the potential it holds.

4.2.5 Design with re-used items

On re-used materials, there is a stark contrast between re-use from the project start (using existing elements from other constructions) and post-life (creating material passports to prepare elements for re-use). This part specifically focuses on project start re-use, with post-life being covered in disassembly.

For the case of re-using existing material for the school projects, all three interviewees agree that the logistical challenges outweigh the benefits of re-use. **the tender manager (P1.2)** outlines the lack of a centralised platform the gather re-used materials, which makes navigating what is available challenging, he states "Assessing the strength and durability of these materials is difficult due to the lack of material passports of end of life constructions in the country". Additionally, he notes that although there are often options for re-use materials, the quality drop is often too severe for clients to feasibly implement. **the development manager (P1.1)** stated that re-using prior material was not the focus, citing similar challenges, but did show how the current materials could potentially be re-used in the future. **the design manager (P1.3)** cites similar challenges such as asymmetric material properties. Overall all three interviewees agree that the re-use of old components is unfeasible as a strategy in this context but do see strong potential in creating systems that ease future re-use (elaborated on in adaptablity and modularity).

In **the information brochure (D1.1)**, Expectations or suggestions to use existing urban structures or elements are not included. All references in **the vision (D1.2)** on re-use focus on creating new re-use opportunities, through relevant strategies like modularity. Project start re-use is only mentioned when highlighting a previous project of theirs (Daltonschool de Poolster). In **the innovation concept (D1.3)**, front-end recycling is only mentioned once in a commitment to use re-used concrete for the foundations. Whether the re-use refers to a re-used element or high-grade recycled concrete is not clearly differentiated. In **the verdict (D1.4)**, there is no further mention of project start re-use.

To conclude, project start re-use was not included due to cited difficulties in logistics, including asymmetric material properties, difficulties in acquisition, and commitment on a project time scale. Both the client and the contractor are in agreement on the applicability of this strategy.

4.2.6 Design with recycled material

The use of recycled material in construction is prevalent of importance to interviewees. **The Tender manager (P1.2)** and **Design Manager (P1.3)** both outline commitments to using recycled material and minimal composites, noting it as an essential method to reduce the MKI (carbon output) of the construction, which is best shown in the documents such as **D1.4)**. **The Development Manager (P1.1)** outlines that the preferable approach is to avoid composite materials to allow for effective recycling.

In **the information brochure (D1.1)** there is a commitment to circularity and making sure no material goes to waste, there is however no explicit expectation or suggestion for building with high-grade processed materials. The approach to circularity does not state favouring re-use of elements or high-grade recycling material as an option of one over the other. This is a deliberate choice to provide the contractors with the freedom to create their innovative concepts.

In **the innovation concept (D1.3)**, Recycled commitments on certain materials are iterated multiple times. This includes a commitment to use brick that is 30-40% recycled, and 60% recycled anodized aluminium window frames. Their biobased commitment (elaborated later) also complements their recycling commitments by making the wooden frame skeleton 100% recyclable.

In **the verdict (D1.4)** although recycling is not explicitly mentioned, it does show satisfaction with the contractor's level of detail in estimating recyclability on an element level.

To conclude, the client left the use of high-grade recycled material as an open choice. The contractor made a strong and realistic commitment to component recycling. The client is firmly satisfied with the strategy used by the contractor.

4.2.7 Design with renewable material

The use of renewable and biobased materials is generally supported across interviews. **the tender manager (P1.2)** and **the design manager (P1.3)** both elaborate on how various wood can be used for elements including walls, floors, and windows, with **the design manager (P1.3)** having years of experience in sustainable wood construction. There is, however, no commitment to fully work with bio-based materials, with the contractor also exploring using dry-stack brick if preferable, and maintaining concrete use for elements such as foundations and floors. **(P1.3)** states that sometimes the benefits of biobased are not outweighed by the necessity to have other factors for example showing that using wooden beams in roofs for example: "has too much depth causing it to interfere with instillations, compromising modularity", because of this they went with steel beams.

The contractor wants to keep their options open, increasing adaptability at the expense of a full biobased commitment. This view is supported by the municipal representative **the development manager (P1.1)** Stated that of 22 applicants, 5 tried to commit to fully developing with biobased materials. The representative expresses reservations towards full biobased commitments, as it depends on the available supply of limited resources on the market. In terms of interviews, the contractor and client are in agreement, to use biobased but not overcommit at the expense of adaptability.

In the documentation, document **the information brochure (D1.1)** at no point explicitly expresses expectation or suggestion to build with biobased. However, there is the implication of sustainability goals that it could be one of the available approaches. In **the information brochure (D1.1)** and **the innovation concept (D1.2)** The primary emphasis is on dimensional standardisation while maintaining a wide range of material options. These material options include many bio-based approaches but are not mutually exclusive with other material options. In **the verdict (D1.4)** the notes that the biobased designs are satisfactory in hitting the subcriteria of sustainability.

To conclude, the contractor offers biobased solutions but does not exceed a commitment to bio-based that comes at the expense of adaptability. The client considers this the right call and agrees with the choice.

5 Case study 2: S&B

Similar to Chapter 5, this chapter follows the same structure but focuses on the Schipbeekbrug en Bolksbeekrug projects (S&B). Starting with case background and nuances, followed by an outline of documents and interviewees, and a comprehensive discussion/comparison of both.

5.1 Case Background

According to the requirements document, the case originates from the need to replace bridges that were declining in structural integrity due to old age. The Bolsbeekbrug was from the year 1960 while the Schipbeeksbrug was initially constructed in 1935 with modifications in 1980. With the national goal of reaching a circular economy by 2050, the Province of Overijssel (the client) decided to use the two bridges as a potential initial case to manage all their bridge assets in a circular manner. With over 160 bridges in their assets, and anticipating 30 replacements by 2042 and around 100 replacements by 2062, they want to develop a framework for circular bridges that matches the national circularity goals.

For the tendering procedure, three companies competed for the opportunity to work with the Province to realise this plan. First, the Province provides a general outline of expectations and context for the contractors. This document called the "Nota of uitgangspunten" is provided to all potential contractors and hosts the information needed to create their bids.

For assessment, three deliverables were to be handed under a premade format by the Province. The first document counts for 40% of the scoring called the samenwerkingsdossier. In the dossier, the client requests the contractor provide a blueprint overview of collaboration between each other and other stakeholders. This document falls outside the scope, as it focuses on business management and organisational systems outside of the engineering field. Although there is some mention of circularity, it is primarily thematic towards an organisation/business management process, rather than an intrinsic circular design strategy, making cross-assessment on circularity ineffective. The second document is the Kansendossier, where the contractor needs to outline three potential opportunities for the venture. Assessed as 30% of the scoring, This is where contractors draft and implement circular design strategies. The third document is the risicodossier, in which contractors need to outline potential risks and how to mitigate them. Two risks are provided by the Province on which the contractor has to create a mitigation strategy, on top of this the contractor has to identify three more risks of its own, which counts for 30% of the scoring.

Ultimately all the dossiers are assessed a score from 1 to 4, with 4 being full points proportionate to the criteria's percentage, 3 being half points, 2 being 0 points and 1 being negative half points. This is done in the gunningsbesslising/verdict document, which provides key insights into the client's opinion of the bid. In the opportunities document (kansensdossier), the company scored 15 points while in the risk document (risicodossier) the company scored 0 points.

5.2 Document Analysis and Interviews

Below is the list of documents and interviewees, as well as their identification tags. They are identified as D or P (Document/person) followed by a 2 for case 2. This is then followed by a number for individual identification.

Table 5.1: List of documents S&B

Document Tag	Document	Document author	Importance
D2.1	Requirements	Client	Outlines requirements
D2.2	Opportunies	Contractor	30% scoring for oppertunities
D2.3	Risks	Contractor	30% scoring for risks
D2.4	Verdict	Client	Elaborates on results

Table 5.2: List of interviewees S&B

Person	Organisation	Position	Experience
P1.1	Provincie Overijssel	Manager Infra	3 years provincial project leader
P1.2	Antea Groep	Circularity consultant	Started in circularity 10 years ago
P1.3	Hegeman Bouw&Infra	Project manager	28 years work towards project leader
P1.4	Hegeman Bouw&Infra	Project engineering	2 years of experience as project engineer

Below the various areas of circular design strategies are discussed, how both the client and the contractor approach them to get insights on the choices made.

5.2.1 Design for prevention

Prevention on a project level is often not given central focus in the procurement phase. All four interviewees note that prevention is often not a step considered any longer in the procurement process, considering that step to be 'passed' by the time it's decided to open a procurement. Optimisation, especially on the element level, received more dynamic conversation, with **the project engineer (P2.4)** mentioning its many potentials on small element levels like railing and lighting, however, **the project manager (P2.3)** warning that on a structural level, the prevention of constructing somewhere often comes at the burden of another part of the construction.

In **the requirements (D2.1)**, responsible minimisation is emphasised as a top of the r-ladder policy, aiming to use the highest policy of the r-ladder 'refuse', when possible.

In **the opportunities (D2.2)**, optimisation approaches are mentioned in two solutions. The first solution, a r-ladder framework establishes 'refuse' as a first resort, however, is generally not elaborated on with the focus falling unto the re-use step. Additionally, in the subsequent solution of wood construction optimisation is used to make the wood as thin as possible while maintaining the necessary structural integrity. Because the documents focus on general conceptual designs, there is no significant detail on how the optimisation would work in practice yet.

To conclude, in both client and stakeholder documents prevention is not mentioned prevalently. There are two key reasons for this. Firstly, in terms of prevention on a project level, that stage has usually 'passed assessment' to begin the procurement process, and contractor stakeholders have no incentive to try and motivate the client to reassess this. On an element level, a commitment to optimisation is made by the contractor and is implicitly stated in documents from both groups. The lack of explicit optimisation is due to it having a more prevalent role in the later level of detail phases of design, rather than conceptual planning.

5.2.2 Designing with quality and maintenance

In the document **requirements (D2.1)** the conventional requirements for 100 years of building lifespan are retained, though there is flexibility if circular designs offer better alternatives for fewer years. One of the most essential points however is optimal management and design for maintenance, which is a major cornerstone of the project as first listed amongst the goals of the bouwteam fase. For all interviewees, ease of maintenance is emphasised over pure lifespan, for example, **the circularity consultant (P2.2)** notes that "I know many bridges in practice do not last 100 years" stating that they often last 50-70 years. He also advises "Design them for 50 to 70 years, but design them in a way that they can be strengthened in a very simple manner". For the company **(P2.3), (P2.4)**, the quality approach is generally to maximise disassembly capabilities to allow for ease of maintenance, elaborated on in later chapters.

Enduring element lifespan is generally not expanded upon in the document **opportunities (D2.2)** either, instead focusing on modular construction and disassembly to allow for maintenance to be done with ease within industrial facilities. This approach favours extending lifespan through industrial repair and replacement rather than maximising the durability of elements.

In **the verdict (D2.4)** discussions concerning this approach were often linked with modular design, and much feedback (elaborated in subchapter on modularity) was about smart goal-setting aspects rather than intrinsic comments on the technique.

To conclude, for the client quality to meet existing standards like 100-year lifespan for beams is stated, however in documents and interviews flexibility is shown to allow for other concepts like modularity. The contractor's response is to focus deeply on modularity and maintenance through industrial repair and replacement. This means that many qualities like ease of maintenance are instead absorbed under the umbrella strategy of disassembly and re-use. While there are differences in client and contractor outlines, the differences in this strategy do not play a decisive role in the verdict.

5.2.3 Design for adaptability

In terms of adaptability, there is some diversity in the interview answers. **The infra manager (P2.1)**, **project manager (P2.3)** and **project engineer (P2.4)** all associate adaption with modular or disassemble design. Generally stating that disassembly and re-use will naturally lead to improved adaptability. This is similar to CB23's mentioning that technical adaptability can be achieved through design for disassembly. The **circularity consultant (P2.2)** takes a different approach and notes the importance of upgradability over disassembly for technical adaptivity. In **the requirements (D2.1)** it is noted that the solution should be 'potentially climate-adaptive' and lead to value creation. Additionally, the prerequisite states that requirements include ways to lengthen lifespan higher than the functional and technical lifespans. Additionally, the disassembly manual should be usable for both a new bridge and a strengthened bridge.

Neither **the opportunities (D2.2)** nor **the risks (D2.3)** explores either climate or demographic-adaptive circular design strategies. Although modular and alternative materials are presented as solutions, these solutions generally focus on a fixed general requirements portfolio. **The Risks (D2.3)** does not outline risks related to climate adaptation, in the interview with **the project manager (P2.3)** interesting insights were provided: "hardwood typically has a 30-year lifespan however by designing in a different way that maximises ventilation, we can guarantee a lifespan of 100 years, it can handle heavy rainfall, as long as the system can ventilate and dry itself" however this is not stated explicitly in the dossiers of **opportunities (D2.2)** or **risks (D2.3)**. Additionally, when looking at scenarios like heavier trucks using the road, plans were discussed for removing the bridge to another location, but exploring upgrading the bridge or planning how a stronger bridge is built was not approached in the interview with **the project manager (P2.3)** or documentation. which causes an imbalance with one of the stated prerequisites of **the requirements (D2.1)**, requiring a design to be upgradable.

To conclude the client makes a clear request for adaptability, in the prerequisites, blueprints for both replacement and upgrading are required, the contractor provides detailed planning for replacement but does not consult upgrading. Additionally, climate adaptability is mentioned (although less prominently) in the client request as well, and although the contractor gave interesting solutions in the interview, this was not reflected in the written documents.

5.2.4 Design for disassembly and re-use

In the document **the requirements (D2.1)** there are many references to disassembly and re-use, or 'modularity' as a potential circular design solution. Industrial, flexible, and detachable design (IFD) is listed as the second of the 'to be applied' instruments (after the r-ladder). The concept behind IFD is to create designs that match technical specifications to allow for detachability and industrial manufacturing/maintenance/swapping. It also states that at its ambition level, it aims to potentially standardise bridges within the organization of the Province of Overijssel as a whole. In the further elaboration of potential starting points IFD is once again listed but as fourth, as well as pro-active norm development is listed as ninth which is closely related to the IFD. In the starting points for innovation IFD stands central, as well as dialogue with market stakeholders to assess technology readiness. **The infra manager (P2.1)** emphasises the importance of modular design but believes that car bridges remain far in the future. **The circularity consultant (P2.2)** expresses scepticism on modular-focused designs stating he is "critical on modularity". A reason for this is that detachable joints reduce the lifespan significantly for components like beams and that modularity should therefore primarily be used for elements with a less than 25-year anticipated lifespan (like railings). There is a general consensus amongst stakeholders that modularity and detachability should be implemented for simple elements such as railing and lighting.

The project manager (P2.3) and **project engineer (P2.4)** both identify modularity as a cornerstone of circular design, with **the project engineer (P2.4)** referring to the modular system as the "utopia model" for bridge building. This also comes forward in document **the opportunities (D2.2)**, where they discuss the opportunity to create a modular framework. They express a plan to create a library of modular component designs, by creating a panel for discussion between the design leader, project manager, and circularity advisor(s), to formulate designs based on the requirements. They also note that its environmental impact can be further reduced by working together with stakeholders such as maintenance, to optimise construction processes.

In **the verdict (D2.4)**, the Province agrees that the solution of modular designing is of increased value, however, holds reservations due to some limitations on the SMART description. For example, there appears to be a lack of clarity on how the discussion phase is translated into the IFD portfolio. There is a clear indication that general requirements, as well as project-specific requirements, are drafted in parallel, however, how this interconnects with IFD is not stated explicitly. Additionally, it notes that **the opportunities (D2.2)** has quantitative price impact assessment for the other two opportunities, but the same is not provided for this solution quantitatively.

To conclude the client requested to explore this avenue in interviews and documents, and the contractor responded with a comprehensive modular plan that makes it the flagship strategy. The contractor has reservations about the price and processes timeline, and how it integrates with the prerequisite IFD framework.

5.2.5 Design with re-used items

On the matter of re-used materials, all four interviewees recognise that there are major logistical challenges. **The infra manager (P2.1)** and **project engineer (P2.4)** both note the difficulty in standardising re-used materials, especially older ones that lack a material passport. They, alongside **the circularity consultant (P2.2)** focus primarily on trying to make smaller elements re-usable, with larger elements generally having too unreliable material passports and underderstandardised characteristics in the present.

Under the solutions of **the requirements (D2.1)** creating a material passport for future re-use was noted as a method of achieving circularity as well as involving multiple stakeholders along the supply chain. In fitting solutions, the re-use of possible components was listed first on top, but it was also listed as one of the prerequisite solutions, which are based on the r-ladder hierarchy.

In **the opportunities (D2.2)** a re-use solution was outlined to use some of the beams that remained in acceptable condition and/or needed manageable reparation could be re-used elsewhere as a 'donor-bridge'. This was based on a flowchart of priorities similar in structure and order to the r-ladder. **The project manager (P2.3)** notes that these beams could potentially be re-used for a cycle bridge elsewhere.

The verdict (D2.4) states that it does not identify the solution in **the opportunities (D2.2)** enough as distinct enough from the prerequisite requirements in **the requirements (D2.1)**.

To conclude, considering the utilization and scanning via the r-ladder is a must, the Province does not view the solution presented by the client as expanding on the project value. Rather than the issue being divergent values, the client identifies a redundancy in the contractor offer from its perspective.

5.2.6 Design with recycled material

All four interviewees recognize the importance of recycling, but also how far recycling has come for the major materials of bridge infrastructure. Steel, concrete, and asphalt are all already regularly recycled as noted by **the infra manager (P2.1)** and **the project engineer (P2.4)**. **the circularity consultant (P2.2)** also mentions this while highlighting that excessive composite use can cause difficulties in recycling emphasising the need to use minimal unique materials per element.

In **the requirements (D2.1)**, Recycling is explored as a method of reducing the use of primary materials, as well as a prerequisite to develop a recycle-passport so that new materials can be recycled effectively.

The opportunities (D2.2) and **the risks (D2.3)** generally do not approach recycling in-depth, with some brevity regarding it in the first opportunity of the dossier, which outlines it as a step after re-use is deemed implausible but before sending to waste. Additionally, the second solution on wood construction notes that the source is recycled wood, which synergises well with renewable material.

The verdict (D2.4) makes no further comment on recycling explicitly.

To conclude, all interviewees recognise the importance of recycling, but since recycling is already common and sophisticated in the Netherlands for infra-construction materials, this policy is often implied. There are some brief mentions of recycling from both the client and stakeholder, however it does not play a decisive role in the verdict.

5.2.7 Design with renewable material

On renewable and bio-based materials, wood construction is of particular interest. The document **requirements (D2.1)** briefly notes the potential for bio-based materials, both in the exemplar solutions, listed alongside recycled materials, and potential climate-neutral materials in the ambition-level table.

Document **opportunities (D2.2)** gives a detailed outline of a potential plan for wood-based construction, including its reduced emission output, cost, and strategies to maintain a long lifespan even with wood design. There is broad consensus between all four interviewees that integrating wood construction, at least to a certain extent on various elements is a good solution. Additionally **the infra manager (P2.1)** and **the circularity consultant (P2.2)** note that there is limited wood-construction know-how left in the Netherlands for infrastructure, and laud initiatives to do so.

In **the verdict (D2.4)** The outlined plan for wooden construction in **the opportunities (D2.2)** is well received, with no further sceptical or constructive comments.

To conclude, the client would appreciate (but does not demand) renewable material. The contractor delivers a plan that is sound and well-received. Both contractor and client are satisfied with the approach of this strategy.

6 Case Comparison

Below is a results table comparing the tender invitation and the design bid for the two cases. First, for each of the strategies, the inputs by the contractor/client are placed for the two cases. Then a vertical and horizontal comparison is made. The vertical comparison compares the client and stakeholder outlooks within the two cases, answering the subquestions Q1 and Q2 respectively. The horizontal comparison compares the client requests between the two cases, and the tender offer between the two cases to answer subquestions 3 and 4. Finally, the comparisons are synthesised to fuind an aswer on to what extent Hegeman's circular design bids match the tender request between building and infrastructure.

Table 6.1: Results table comparisons

Aspect	Case 1: IPS	Case 2: S&B	Comparison
Invitation by client to tender	• The client makes no explicit mention of requiring the contractor to take measures in **prevention**. • The client expects design for **quality and maintenance** in the form of social requirements to make the design as user orientated as possible. • The client wants **adaptability** on a framework scale, the modular system should not just make adaptive designs, but be intrinsic adaptive to changes as a framework. • The client identifies the term flexible as key for their **disassemblable and re-use** policy, however, leaves means of achieving this to the contractor. • The client does not expect the contractor to use **re-used** materials for construction, additionally **recycling** is not explicitly mentioned, it is implied however that some of these measures will need to be taken to reach target carbon outputs. • Lastly, design with **renewable** material is invited, but not mandatory.	• The client requires the contractor to use the r-ladder, prioritising refuse as a **prevention** policy, context from interviews and documents show that in practice the expectation for contractors to deliver refuse solutions are not prevalent. • For **Quality and maintenance, adaptability** and **disassembly and re-use** the client makes prerequisites for the contractor to work with the IFD system as well as making blueprints for both disassembly and upgrading/strengthening bridges. • The client also invites the contractor to create a climate adaptive solution. The client expects the contractor to scan for potential **re-use** materials if possible, specifically by using the **r-ladder** system. The clients expectations for **recycling** is implied but limited in explicit statements due to it being common in the Netherlands. • Lastly, the client appreciates initiatives to build with **renewable** materials.	• For both tenders, **prevention** does not play a key role as the phase has 'already passed' once procuring an engineering contractor. • Both clients invite solutions such as **quality and maintenance, adaptability** and **design for disassembly**, while the IPS client leaves more to the contractor, the S&B client necessitates a series of prerequisites. While IPS criteria can be covered through modularity, S&B adaptability criteria also requires up gradability, meaning components should not just be movable, but reinforced component variants should be developed that are easily implementable when technical demands require it. • While IPS does not cover prior **re-use** material, S&B does via method of an available resource scan. Both tenders invite **recycling** and **renewable** material use as means to reduce carbon output, but do not provide guidelines or minimum demands to do so.
Design bid submitted by Hegeman	• The contrator does not offer solutions on "refuse" for **prevention**, however it does offer various optimalisaiton approaches embedded throughout the designing phase. • The contractor aims to achieve **quality and maintenance** by making the schools desirable to be in through maximising natural light, quality air and temperature control, ease of maintenance is achieved through technical **adaptability**. • This technical adaptability is based on a modular system, deeply interlinked with **disassembly and re-use**. In the modular system, every link is detachable with ease using layers of brand. • **Re-use** of previous material is not applied due to a variety of logistic and cost factors. The contractor does make a commitment to **recycling** various elements as a means of lowering the carbon output. • Lastly **renewable** materials are used when possible, but non-renewable options are kept available to maximise **adaptability**	• In terms of **prevention**, the contractor does not offer solutions in terms of refusing or avoiding, but indicates plans to embed optimisation throughout the project. • Quality and maintenance, adaptability and **dissasembly and re-use** are taken together under a modular system, which allows for industrial repair and replacability of components. The company makes a **re-use** plan based to re-use some beams for a potential donor bridge using a flowchart similar to the r-ladder. **recycling** is not mentioned in depth due to its importance within established norms. • **Renewable** material is looked at by potentially building with wood that can maintain a long lifespan.	• For both projects, the contractor offers **prevention** solutions in the form of optimisation embedded throughout the project. • They both attempt to encompass **quality and maintenance**, **adaptability** and **dissassembly and re-use** within modularity, with both creating a portfolio of modular components that can be brought together (and seperated) to create an design that can change and be maintained easily for user need. • For **re-using** prior materials, the IPS project does not offer solutions and neither are they requested to do so, for S&B, they identify a solution to re-use the old beams or the expiring bridges in a donation bridge. • Both projects offer **recycling** solutions, with IPS going more implicit and concrete on the recycled materials, while for S&B this is more implied by national norms. • Lastly both IPS and S&B offer to work with wood for **renewable materials**.
Comparison	• Neither the client nor contractor make significant mentions of the **prevention** policy, but the contractor takes the initiative to include optimization methods throughout the project. • For **Quality and Maintenance**, the client aims for a socially sustainable solution that is user-orientated, the contractor delivers by implementing quality measures such as maximising natural light, clean air and temperature control, while covering maintenance in their technical **adaptability.** • For **adaptability**, the contractor increases this by providing an assortment of possible usable materials as well as layout configurations, the only definitive aspect is the dimensional grid, this matches the client which seeks an adaptable framework that can anticipate various future scenarios. The client requests a high level of flexibility, and the contractor delivers by means of making as many components detachable as possible in a modular framework, essentially **designing for disassembly**, especially under the means of modularity. • There is limited **re-use** of prior materials, but both the contractor and client agree that this is not necessary. • The client invites **recycled** and **renewable** material use to control carbon output, the contractor provides recycled solutions for various elements and uses renewables when possible, but does not prioritise renewability over adaptability or modularity.	• In terms of **prevention**, avoid policies are not expected or delivered, some optimisation solutions are provided on the initiative of the contractor. • For **Quality and maintenance**, **adaptability** and **disassembly and re-use** the contractor differs from the client with the contractor emphasising modularity as the primary approach. Beyond modular and detachable solutions, the client also explicitly requests upgradable designs against increasing technical demands, which the contractor does not make explicit plans for in their modular framework. Additionally the client requests a potentially climate-adaptive concept, which the contractor does not cover further. • In terms of **re-use** the client expects prerequisite scanning of usable material via the r-ladder, because it is a prerequisite, the client considers the contractors further input on re-use as redundant. • **Recycling** is not further discussed but there is implied agreement to use standard recycling techniques. The client invites the use of **renewable** material which the contractor acts upon by using wood, satisfying the client in this area.	• For IPS, the contractor delivers on the client request and sometimes takes the initiative to expand beyond it. For both projects and stakeholder groups, **prevention, renewable materials and recycled materials** strategies and feasibility are agreed upon. • In the policies that fall under modularity, including **Quality and maintenance, adaptability** and **disassembly,** both clients require flexible solutions which the contractor offers through a modular framework. While this modular framework overlaps fully with the IPS criteria, there are some differences in necessary **adaptability** policies that prevent complete overlap between modularity and the S&B criteria. This includes the necessity to be able to upgrade components (for example in case of increased load), which the current modularity framework does not accommodate as the components of singular type have uniform technical specifications. Additionally the area of climate adaptability is not covered explicitly in S&B, which the client indicated is an important risk to assess. • The last difference is that although the contractor and client agree not to explore prior material **re-use** in IPS, the strategy is necessary for S&B. Due to its prerequisite necessity however, the client considers the contractors additional input to be superfluous in the area.

7 Discussion

In this chapter, the outcomes of the prior table are discussed with an interpretation of the findings. This is followed by implications of the findings both theoretically and practically. This in turn is followed by recommendations and ultimately limitations as well as potential future research.

7.1 Interpretations of findings

To summarise the findings, the role strategies of prevention, recycling and renewables are generally agreed upon across both the cases and stakeholders. For recycling this may be expected as it is commonly used in Dutch norms. For example Eberhardt et al., 2022 identifies recycling as one of the most common terms of circular strategies in literature, highlighting how its significance and widespread use has made it a strategy widely adopted in this sector already.

Quality & Maintenance, Adaptability and Disassembly can generally be combined under modularity from the contractor's perspective for both cases. This matches well with IPS's focus on 'flexibility', as the modular components can adapt to various social and functional needs. On the other hand, for S&B besides industrial flexible detachable, there were expectations for adaptability outside of modularity. In adaption, two technical needs not encompassed by modularity are noted, one is climate adaptability (a suggested strategy), while the other was a prerequisite strategy of upgradable designs. On Hegeman's modular designs, climate adaptability was explored in interviews but was not presented on paper in the risk dossier. No explicit plans were made on up-gradability in either documentation or interviews. Modules were designed to be movable to a variety of locations, however, no plans were made to for example create higher load-bearing modules by adjustment to the standard module. To conclude, synergising the three strategies under modularity was effective for IPS, due to socio-functional adaption being at the core with less demand for structural adaptability. For S&B, adaptability included upgrading the technical capabilities of components, which adds another dimension not explicitly taken into account by the contractor.

For the re-use policy, Hegeman matches the client in both cases but in different manners that change the outcome. For IPS, Re-use on the project start is not expected and Hegeman does not intend to implement it, placing the contractor and client in agreement on their positions. This is because there are many challenges in gathering information for -reuse in infrastructure, with papers such as Iacovidou and Purnell, 2016 highlighted that these are universal challenges. These challenges include finding appropriate and matching material in an appropriate timescale, gathering certifiable material properties, and the logistics of storing and marketing re-used components. van den Berg et al., 2024 also notes that many regulatory barriers prevent the re-use of prior material.Most interviews also aligned with this papers findings of significant implementation challenges.

For S&B, the contractor expects the implementation of the r-ladder and in turn looking at re-use as a prerequisite of their system process. In S&B, Hegeman offers potential re-use for old components in their opportunity-dossier, however, due to the client including re-use scans as part of the prerequisite fixed process, it considers the contractors contribution to be superfluous.

To conclude, Hegeman's tender does not match the client request specifically in the area of adaptability for infrastructure. The research also showed that in some cases too much overlap (such as re-use for S&B) with client prerequisites can hamper the contractor.

7.2 Implications and research contributions

The case study makes a series of implications on how circular design strategies can differ in applicability between construction sub-sectors.

Existing theoretical frameworks include the entire construction sector in a combined process, for example, including Rijksoverheid, 2023 and Platform CB'23, 2023, with technical reports that zoom in on strategies generally focusing on only one aspect (such as buildings for Van Vliet et al., 2021) or combine the full construction sector for example Dijcker and Schepers, 2018. These overviews, holistic in approach, generally make little differentiation in construction and infrastructure approaches. The research contributes by indicating that within the two cases, a clear need for expanded focus on technical adaptability is needed for infrastructure. This expansion goes beyond strategies outlined in cb23's design for disassembly (which encompasses technical adaptability), as in practice certain clients may favour designs that are not necessarily disassemblable which can weaken design but rather are made with intention to allow for reinforcing in an intentional manner.

Secondly the research takes a lead in analysing tender-contractor interaction in early emerging procurement techniques. Previous papers such as Lingegård, Havenvid, and Eriksson, 2021, and Eriksson et al., 2019 exploring how circular innovation can be advanced with new collaborative procurement models. This research explores how this applies to more specific collaborative procurement models like building design teams and innovation partnerships. The research shows that as procurement becomes increasingly collaborative, synergy between contractor and client articulation of circular strategies becomes increasingly important.

Lastly the research presents further on how considerations differ between theoretical and practical stances. Papers such as Corvellec et al., 2022 mentions reservations against circular principles including for example "definitional quagmires", which is also present in the two cases where often different terms are used to discuss overlapping or closely overlapping concepts. Papers such as van den Berg et al., 2024 for example also notice how interviews highlight further issues that are not as prevalent in literature and/or documentation. Throughout the interviews challenges related to regulations, logistics, pricing and other factors were generally discussed more thoroughly, effectively, and openly than in literature, noticable as well in the scenario of these two cases. The research in the cases contributes in showing the importance of conducting interviews in parallel to other methodologies is signficiant for applications of circular strategies.

In terms of practical contributions, the research results are generally highlighted in the upcoming recommendations heading. Generally speaking beyond the cases, practical contributions include the value of assessing contractor and client articulations against one another within the domains of specific strategies. By putting these strategies and policies on a row against one another, contractors can effectively identify where there remains a gap in reaching full compatability with client criteria.

7.3 Recommendations

For Hegeman Bouw & Infra, recommendations regarding the S&B project include:

Focus not just on creating a modular system that can adapt to a series of spatio-functional scenarios, but also look into adapting to increasing technical demands. An example approach would be creating modules that are designed to be upgradable on-site with ease so that they can carry an increased load in future scenarios.

Another recommendation is to acknowledge client prerequisites, but create detailing concepts for opportunities outside the scope of the client prerequisites. By focusing on opportunities not included in the clients existing process, the space to discuss innovative approaches is increased and redundancies are mitigated.

Lastly a recommendation is to explore more environmental/circumstantial aspects of the risks of circular design. Potential risks to explore could include for example increased load bearing demand in the region, which would allow for explicit detailing towards the client that the modular system encompasses their prerequisite policies such as up-gradability. Another potential risk would be to explore climate adaption such as higher moisture, rainfall or water level. This is an especially relevant pairing with for example the opportunity to build with wood. Although mitigating the effects of decay by water exposure was discussed in interviews, by explicitly adding it towards the risk-dossier the modular framework is shown directly to be adaptive to likely future scenarios.

7.4 Limitations and future research

One of the key limitations of this study lies in its scope, which is primarily centred on circular design strategies within the procurement process. By focusing exclusively on these strategies, the study does not take into account organizational and managerial aspects that may have influenced the outcomes of the procurement decisions. Factors such as internal decision-making , collaboration models between stakeholders, organisation strategies employed by contractors and clients could have played a significant role in shaping the verdicts. The lack of these elements means that while the study provides insights into the alignment and misalignment of circular strategies, it does not provide a complete answer on why contractor bids are or are not selected.

Another notable limitation is the narrow selection of case studies. The analysis is based on only two procurement cases, one from building construction and the other from infrastructure. While these cases offer valuable insights into sectoral differences in circularity, a broader dataset covering more projects, diverse contract types, and varied regional procurement frameworks would be necessary to allow for extrapolation. Circular procurement in construction is highly contextual, influenced by factors such as regulatory environments, geographical location and contractor-client relationships. Expanding the range of cases would allow for a more comprehensive assessment of how circularity is implemented across different procurement contexts. Additionally, the study's document selection is constrained to a subset of procurement materials, limiting the depth of analysis. While the research focuses on client request documents, contractor bids, and final verdicts, other critical documents, such as the samenwerkingdossier from the S&B case and the plan of approach from the IPS case, were not included. These documents provide deeper insights into the organizational and process-related aspects of the procurement process, including collaboration structures, internal decision-making frameworks, and stakeholder engagement strategies. Incorporating such materials in future research would enable a more integral analysis of both tenders, allowing for a better understanding of how circular strategies are framed and evaluated in tandem with broader project management considerations.

Future research could address these limitations by adopting a more holistic approach to circular tender analysis. This could involve integrating both circularity and organizational strategy perspectives to understand how systems process also play a role in procurement selection. Conducting comparative studies across multiple tendering models, including design-build, building design teams and innovation partnerships, can provide insights on how effective circular integration is in the design types. Expanding the scope of document analysis to include additional tender-related materials would also enhance the depth, providing a more angles to approach the results of how a tender plays out.

8 Conclusions

The research aims to identify how contractor and client strategies match or diverge between two cases in building construction and infrastructure. The study addressed the main research question by means of the four sub questions, providing insights on how contextual differences can impact the significance, interpretations and detailing of strategies.

The study firstly provides a general understanding of the tendering process for construction projects in the Netherlands. It establishes a foundational system during the tendering phase that allows identifying the most important documents (and interviewees) for drawing conclusions on what shaped the outcome of the tendering process. It also outlines the circular design strategies of CB23, using these foundational concepts to cross asses the prevelance of strategies between contractor and client documents.

The study then explores each of the two cases individually, tackling all seven of CB23's design strategies. for each strategy, they are generally introduced by discussing relevant results from the interviews, that provide an overview of stakeholder perspectives on the strategy. This is then followed by an analysis of documents seeking explicit mentions of the policies. With the help of verdict documents, concluding statements are made on wether the client and contractor strategies match one another.

Lastly the research delivers a synthesis of the results between cases and stakeholder groups, aiming to ultimately identify on which key strategies the contextual differences hinge upon. This outcome is then discussed in terms of its research implications, actionable recommendation and the limitations of the current scope.

To summarize, the research has limitations, especially the narrow scope that limits drawing conclusive statement on why the results of the tendering process differ as a whole. The findings, however, do open discussion on whether building construction and infrastructure should be approached in the same manner for circular strategies, or whether certain dimensions, for example the sub-aspects of adaptability need to be further emphasised for relevant sub-sectors. The research advances theoretical understanding of differentiating circular strategies and identifying their best suited contextual applications. The research also advances practical understandings for contractors such as Hegeman Bouw&Infra on how to approach tenders in the two sub-sectors differently.

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Appendices

Interview P1.1 (Total 55 min)

Topic	Summary
Experience (0-10 min)	Works as strategic advisor for purchases, primarily in the physical domain. Background in civil engineering. Founder of the innovation partnership.
Prevention (19-21 min)	By bringing the contractor in earlier, dynamic changes in optimisation especially time efficiency are present.
Quality (29-33 min)	Combines closely with flexibility as a concept. By changing the construction over time it naturally has a longer lifespan.
Adaptability (21-27 min)	Is important, should be noted that a change in offer causes a change in question. Asked the market "what can you do" as the most appropriate strategy. Left strategic choices to the market. Talks about adaptability on the macro level. Adaptable by having diverse array of tenders that go through a natural selection process.
Dissassembly (8-20 min)	Has experience on the manufacturing assembly line, notes that it is "strange how we do it in construction". Goal of the innovationpartnership is to achieve an industrial way of construction. Modularity is very feasible, also notes more feasible than construction.
Re-use (33-37 min)	Agreed with colleague "let it be" since the city is growing and there is such rapid growth. Start with the questions of new construction.
Recycle (37-41 min)	Returned to conversation on re-use
Renewable (41+ min)	Personally chosen to not force the use of wood. Makes you incredibly dependent on global wood supply. Of 22 companies that really participated, there were around 5 who fully committed to bio-based.
Reflections	The technical process is not particularly difficult, the difficulty is approaching the future. Need to improve scenario analysis and improve question analysis by clients.

Interview P1.2 (Total 50 min)

Topic	Summary
Experience (0-3 min)	6 years working in hegeman, started as process engineering verwerving, then tendermanagement. Manager verwerving services. Company leader Hegeman Modulair.
Prevention (6-9 min)	Focus on implementing new materials, they want future reflective stability. Should be useful for other purposes in 30 years, overdimensioning policies, new new. No mention of preventive prevention

Quality (9-13 min)	Overdimensioning elements so that the quality remains longer. Less is more.
Adaptability (throughout)	Once again overdimensioning of elements allow for adaptability towards future expansion
Dissassembly (throughout)	Full project is designed to be modular, flagship concept for the project.
Re-use (throughout)	No re-use plan of old materials because its not necessary.
Recycle (13-14 min)	Has to use secondaire material to minimise co2 emissions. Good example for rest of netherlands on how to implement in the design process.
Renewable (throughout)	Mentions using wood as one of multiple option.
Reflections	Note: conversation drifted much into practical limitations such as cost and logistics.

Interview P1.3 (Total 49 min)

Topic	Summary
Experience (0-3 min)	4 months Hegeman,architectural engineering. Consultancy. Started as carpenter and became teamleader. Worked in fully woodworking residential construction before Hegeman.
Prevention	Did not consider prevention. Dont ask gemeente if you need less space for the school.
Quality (17 min)	Use modularity to improve maintenance capability. Separate wood system from water system. Aluminum plate above the roof system. Taking into accounts dimensioning like adequately large cooling system.
Adaptability	Standardising grid by being able to re-use remade ontworpen.
Dissassembly (4-10 min)	Everything we do is based on disassembly and adjustability. Minimal material loss when you adapt things. Layers of brand, outer layer is for thermal insulation, but does not have function hold electrical cables. Every layer has minimal responsibilities. Dont merge function layers. Modularity is more important than fully renewable, also took a while to get used to from his ecological wood building experience. There are too many options sometimes. Zooming in on the options there are too many, we want to reduce the options to allow for standardising.
Re-use	Not taken into account. Dimensions are too difficult to get at the right quantity. Standardisation will make re-use of old materials harder.
Recycle	Reycled beton and steel. Market is not ready for it, very small volumes for high price. If we can we will do it, but practically there are some difficulties. Logistical difficulties with aligning with project timeline.
Renewable (10-15 min)	Use wood but not always, sometimes a concrete floor is better due to its lifespan. Steel beam holds the wood together, wood beam would need more depth getting in the way of cables. Priority is avoiding hybrid materials.
Reflections	"We lay the dimensions, and then try to produce as much as possible in those dimensions".

Interview P2.1 (Total 31 min)

Topic	Summary
Experience (0-3 min)	Three year project leader at Province Overijssel, given task to procure contractor for old bridges.
Prevention (29-31 min)	Looked at leaving the bridges but strengthening them. Unfortunately this was not an option due to the old age of the bridges. But does consider it in the beginning of their processing. Strengthening hints to adaptability.
Quality (3-5 min)	For sustainability its important but different for circularity. Can come at the expense of Re-use, re-use is preferable.
Adaptability (9-11 min)	Belongs with modularity, adding modules to change/adapt purpose. Make it simple.
Dissassembly (7-12 min)	Very important for bridge construction. Very high value that a bridge can be easily deconstructed. Costs a lot to remove liggers. For car bridges far in the future. Risico van handeling. Is difficult but should be done, there are possibilities but trust must be built.
Re-use (5-7 min)	Can be done on a national scale. Issue is storage logistics. Only realistic on a large scale central platform.
Recycle (13-14 min)	Already applied on a large scale, good value. Perfect with asphalt and concrete.
Renewable (14-19 min)	For car bridges too far in the future, useful for bike bridges. Would be nice for car bridges but not sure who would take initiative. More applied wood in germany but lack of knowledge in NL. Wood rotting can be a major issue.
Reflections	Multiple year planning can cause difficulties with financial planning. Need to start working on it from the start.

Interview P2.2 (Total 48 min)

Topic	Summary
Experience (0-1 min)	Works at Antea with a business background, purchase management. Predominantly in infrastructure and started around 10 years ago with circularity. Step by step his knowledge expanded
Prevention (2-5 min)	Does not encounter it often because the client already wants it. This phase has usually passed by his encounter. On governing level he does advise this. Re-use is also a form of prevention on element level.
Quality (12-16 min)	Does not have a decisive answer, in practice most bridges have shorter lifespan than anticipated. Most will in practice last 50 years. Load differences increase. Does not occur often in the past which is a strong indicator that the future technical lifespan is not realistic.
Adaptability (17-22 min)	Is favourite in infra. In construction its easier but in infra its not regular and standard. Very few designs made to be adjustable, make connections between beams that can be strengthened or expanded if traffic load increases. There are some bridges that have 'ugly' extensions because the expansions were not planned. Clear distinction between adaptability and modularity.

Dissassembly (5-10 min)	Within the province it's important, but it's a very difficult one. Many clients want something new. Often associated with re-use. Personally advocates removable only for elements such as railing or those that are expected to last less than 25 years, demontable bridge does too much damage to quality. If you don't plan on touching in 100 years why bother with detachment. Critical on it. Only do it with short lifespan designs.
Re-use (23-27 min)	Uses the seven model of Brandt, comes from residential buildings, and tries to identify shells for infra. Each element has different shell and lifespan. Try to find the short lifespans for re-use should as asphalt and railings. Re-use for big elements like liggers are sometimes more expensive than new ones.
Recycle (27-31 min)	Asphalt is regular, concrete you need to make choices. Pick between preferring reuse or recycling (minimise composites). We have concrete stronger with lower MKI but cannot be recycled because of composites. On a material level prefer recycling.
Renewable (31-37 min)	Passengers bridges can be made of wood. For a ledge or lantern wood is great. Per element is important. Sometimes recycled aluminium better than wood. Lack of material science knowledge on construction. The whole sector has too few material scientists 1800 people but 4 people with material knowledge. Concrete is the norm
Reflections	Look at adaptable to balance lifespan with functionality. Normally technical lifespan is chosen but also interest per stakeholder.

subsection*Interview P2.3 (Total 27 min)

Topic	**Summary**
Experience (0-2 min)	Work 28 years as project worker, become a project leader starting in realisation. Last 2 years lots of bouwteams where they are much earlier in the process.
Prevention (21-24 min)	If a bridge is asked what can you not do? Could explore for certain elements, however it is always give or take. Not doing one thing usually means an expansion of tasks in other areas. Remains difficult. Often a lack of information for previous passports makes it difficult to use existing structures.
Quality (4-6 min)	Improves with modularity for 100 year lifespan. For example painting it more efficient because it can be swapped out in factories rather than work on site.
Adaptability (9-15 min)	Standardised through modularity naturally leads to adaptability. If the traffic increases you can always move an element to become a bicycle bridge. Adaptability means you often need to add a layer which does work perfectly with modularity. Could move bridge in factory to strengthen in. Not explored in depth in their example.
Dissassembly (2-4 min)	We didnt give an exact plan of this is how we are going to do it, but the main goal is that they are interchangeable at a certain point. Example is a leaning.
Re-use (6-8 min)	Very hard to do, due to functional asymmetry, especially during a period before material passports. The report said no element could be re-used, there were beams that could be taken out to use for bicycle bridges.

Recycle	Forgot to ask, however many common answers regurgitated that they are confident that steel, concrete and asphalt are already well and systematically recycled.
Renewable (15-21 min)	Many methods to have high lifespan wood. By adjusting wood design to stay ventilated and dry a lifespan can be promised up to 100 years over the 30 years. A lot of missing knowledge in wood design. Condition depends on how its taken care of. More or less rain is not very important as long as it can dry itself rapidly. Explore how fighting moisture by making rapidly heating design.
Reflections (24+ min)	Potential friction with partnership. Mostly focused on bouwteams model not having a lot of experience in contract form. In terms of content we are quite confident, however hard to gauge what the client may really want.

Interview P2.4 (Total 44 min)

Topic	**Summary**
Experience (0-6 min)	Civil engineering and commercial business study. Works mostly in the tender phase. Already worked with sustainability in middle school, already a few projects in the direction of circularity. Previous municipalities and provinces made designs and gave the contractors the role to make it. Later it moved over to bouwteams where the contractors had the main role in designing, developed within the last 4, 5 years in infra, compared to earlier in building construction.
Prevention (7-11 min)	Looked into preventing new construction by using older elements in design, unfortunatly not commonly feasible due to limitations in prior planning for re-usability.
Quality (18-23 min)	Design for long use needs to be done together. Asset management should be done by provinces, but contractors have sub-contractor knowledge which requires working together. Maintenance planning should be done together but maintenance itself should be with province. An example would be an extra asphalt layer that ruins the modularity..
Adaptability (11-18 min)	Can be done however there are many layers built above the beam. You need to create a new connection to strengthen, we do not take this into account unless explicitly asked. Needs to be done really far in advance, many clients find it too scary. They asked for a design process. Depends on layers of brand like asphalt or railing.
Dissassembly (23-26 min)	The utopia model, that would be perfect, by standardising you can make it a lot more efficient. Stakeholders such as manufacturing are very important in this and to adapt with time.
Re-use (31-34 min)	Very nice idea, very high logistical constraints. Need to be able to standardise elements, responsibility of ownership and disassembly. Difficulty in selling because line up of projects make logistics unfeasible.
Recycle (34-40 min)	Very well advanced for concrete and asphalt. Also very developed in steel. Can be used for example for gabions.
Renewable (27-31 min)	Biobase can potentially non-biobased modules 1:1 for the same dimension. Functional requirements are required that make difficulties to use biobased, especially since functional requirements are commonly designed for concrete.

Reflections (40-44 min)	Very hard to get a new idea on paper. Very new process so its hard to get used to. Still believes strongly in their ideas. Per risk it was really hard to get all the ideas across with the limited space provided. Still strongly believes in the chances and opportunities. Works well in IPS.