Integrating Circularity in Initiation Phases: A Case Study of Two Bridge (Re)Construction Projects

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Integrating Circularity in Initiation Phases: A Case Study of Two Bridge (Re)Construction Projects

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Abstract

The increasing attention for the circular economy in the construction industry can be explained by the industry's substantial amounts of raw material usage, waste production and contribution to global greenhouse gases. Part of public clients task is the renovation and replacement of bridges that (nearly) reached their end-of-life. The need to incorporate circularity in these projects is well-recognised by public clients. However, current project management and processes do not consider circularity explicitly, which may impede adoption of circularity in bridge projects. Therefore, this study aims to formulate recommendations towards the Province of Overijssel on the organisation of the initiation phase of circular bridge (re)construction by analysing the current process in practice and comparing that with state-of-the-art insights on circular development. Doing so, the initiation phase of a real-world project was studied, which covers two bridges that are representative for other bridges. A pattern matching strategy was selected to explain differences and similarities between theory and practice in the qualitative analysis of the data collected by observations, interviews, document analysis, and a panel discussion. This study shows that four processes are particularly important for circular bridge development from a client's perspective, which are 1) formulating the project ambition, 2) composing the project team, 3) deciding to refuse, renovate or replace, and 4) consulting the market. Theory and practice of these processes match to certain extent. Based on the insights, it can be concluded that there are certain points desired for the initiation phase, these are mainly 1) circular ambitions on asset management level, 2) procurement- and circularity advisors in a project team with circular commitment, 3) circular indicators in performance-cost-risk assessment, and 4) early involvement of market parties. These insights provide further clarification for science on processes in the initiation phase of circular bridge (re)construction, and allow practitioners to use the insights and reshape their initiation phase for future bridge renovation and replacement projects.

Keywords: Circular Economy, Bridge Construction, Project Processes, Project Management, Pattern Matching

1 Introduction

Reducing emissions and transitioning to a circular economy (CE) in the construction industry is relevant since the industry is notorious for its significant amount of raw material input, construction and demolition waste, and contribution to global greenhouse gases (WEF, 2017; Pomponi & Monchaster, 2017). To illustrate, the European construction industry is responsible for 46% of total waste generated (Gálvez-Martos et al., 2018). Next to that, 25-40% of CO2 emissions originate from the construction industry (WEF, 2016). With the Paris Agreement as foundation, the Dutch Climate Law states to reduce CO2 emissions by 49% in 2030, and 95% in 2050, compared to the year 1990 (Rijksoverheid, 2019). Recently, the new Dutch Cabinet increased their ambitions to 55% CO2 reduction in 2030, and a climate-neutral 2050 (Rijksoverheid, 2021). It is – among most practitioners, policymakers, and scientists – well-recognised that change is needed. This can be illustrated by the rising number of studies in the field of CE in the construction industry and the variety of challenges, suggestions and findings that these studies introduce (Hossain et al., 2020). CE is one of the means to be more sustainable (Anastasiades et al., 2020). A well-known definition of CE is "an industrial system that is restorative or regenerative by intention and design" (Ellen MacArthur Foundation, 2013, p. 7). In other words, resource input, waste, emissions and energy leakage is minimized by slowing, closing and narrowing material loops (Geissdoerfer et al., 2017). Therefore, the Dutch Government aims to be circular in the year 2050 and the Province of Overijssel is following this vision (Provincie Overijssel, 2020).

Currently, a national large-scale renovation and replacement program of civil engineering structures that reached the end of their technical life is established to ensure the quality and safety of Dutch civil engineering structures. Conventionally, asset- and project management decisions with respect to replacement and renovation were taken based on criteria such as performance, expenditures, and risk

(Van Houten & Zhang, 2010). However, nowadays sustainability, and thus circularity, are key factors to incorporate in asset- and project management decisions (Korse et al., 2016).

Much research has been done on conceptualising CE in the construction industry (Geissdoerfer et al., 2017; Kirchher et al., 2017). However, there is limited research and limited wide-scale application of circular thinking in the built environment at the product and component level, such as infrastructure works (Adams et al., 2017). This is made explicit by Van den Berg et al. (2019), who state that design professionals lack systematic methods that help them to implement circular thinking in real-world circular design practices. Similarly, it can be observed that project management methods – such as Prince2, GOTIK, and PMBOK – do not yet incorporate sustainability or circularity as part of project control factors (AXELOS, 2017; Winch, 2010; Sears et al., 2015). This all hampers the adoption of circularity in construction projects, since the management of circular construction processes will not be effective or lead to circular outcomes except if it is based on CE (Venselaar et al., 2019).

Especially the initiation phase showed to be key for circularity in construction projects (Gerding et al., 2021; Sanchez & Haas, 2018). As these studies did not investigate circular bridge development of bridges that reached their end-of-life specifically, this research aims to formulate recommendations towards the Province of Overijssel on the organisation of the initiation phase of circular bridge (re)construction by analysing the current process in practice and comparing that with state-of-the-art insights on circular development.

The paper is structured as follows. Section two discusses theory on the existing body of knowledge on how to integrate circularity into the initiation phase. Next to that, it elaborates on barriers and enablers for implementing circularity in general, in bridge projects, and for clients specifically. In the third section the method is described. Section four systematically discusses the empirical findings of the case study, including an explanation on differences and similarities. Section 5 discusses the insights and contributions that follow from the differences and similarities. It also describes the limitations and directions for future research. Section 6 concludes the paper.

2 Theoretical Framework

This section firstly elaborates on circularity in project-based construction projects. In the literature review, four processes are identified that are key for circular development in the initiation phase, which are 1) formulating the project ambition, 2) composing the project team, 3) deciding to refuse, renovate or replace, and 4) consulting the market (Section 2.2-2.5). Section 2.6 provides additional context on barriers and enablers on circularity in construction.

2.1 Circularity in project-based bridge construction projects

The renovation of existing bridges and other civil engineering structures is known for its project-based character. Projects are temporary organisations and rely on a resource base (Winch, 2010). Projects follow a predefined set of phases in which processes take place. These processes have an input, certain tools and techniques, and an output. The output is the input for a next process, or a project phase deliverable, or both (Project Management Institute, 2017). The initiation phase in this research implies the start of the project where broad project characteristics are defined where the client is responsible for (Sears et al., 2015). The follow-up phases are the planning-, execution, monitoring- and control-, and closing phase (Project Management Institute, 2017). Previous research suggests to extend the initiation phase in CE projects to provide flexibility, the possibility to experiment and create space for new ideas (D'Coutho, 2020). Also, research developed a collaboration framework from the initiating party perspective and stated that processes in project phases require adjustments for CE projects (Leising et al., 2018).

Proven methods in project management focus on controlling factors, such as costs, time, quality, benefits, risks, scope, information, and the organisation itself during all project phases (AXELOS, 2017; Winch, 2010; Sears et al., 2015; Project Management Institute, 2017). However, sustainability and circularity are not explicitly incorporated in these, while it is shown that early usage of CE thinking improves later adoption of circularity in the project execution (Gerding et al., 2021; Sanchez & Haas, 2018). Versteeg Conlledo (2019) developed a framework by combining the impact of circularity with the control factors of project management, without adding circularity as separate factor. So, CE in project

processes affect the control factors and therefore control factors have to be adjusted accordingly. Further, literature suggests that circular construction projects should include distinct decision rounds with appropriate methods (Sanchez & Haas, 2018). These decision rounds can be seen as processes that need to incorporate circularity to eventually (re)construct circular bridges.

So, circular projects require specific adjustments to processes in the early phases of projects (Leising et al., 2018). Specific processes in the initiation phase are derived from literature by the researcher, which will be elaborated upon next. First, it is desired to create an effective project organisation that is suitable for the size, scale, and complexity of the project (AXELOS, 2017). Circular projects differ since these require new competences, knowledge, roles, and an integral approach (Platform CB'23, 2021a). Members preferably have the same commitment, circular vision, and philosophy (Versteeg Conlledo, 2019; Leising et al., 2018). Second, the project ambition should be stated by developing a project brief and later a project initiation document – or project plan (AXELOS, 2017). For circular projects, the circular ambitions need to be defined and are the basis for the continuation of the project (Venselaar et al., 2019; Versteeg Conlledo, 2019). Well-defined circular ambitions increase the project success (Sanchez & Haas, 2018). Third, when working on bridge projects that are end-of-life, it is necessary to decide what to do with the bridge and how that will be done. More specifically, an investigation on the investment decision about bridge renovation or replacement is desired (Rijkswaterstaat, 2015). The choice for replacement or renovation has substantial implications for the circular design strategies to choose (Dijcker et al., 2018). Considering the 9R-framework, refusing to start bridge (re)construction is also an option, however this requires control measures on the bridge, such as heavy traffic ban or road closure (Frangopol et al., 2017). Other options of the 9R-framework are the reuse and recycle potential of bridge components (Van Offenbeek-Kuipers et al., 2021). Fourth, to have a circular procurement process, a market consultation is desired and even mandatory according to a developed guideline (Vos, et al., 2019). This is a process before the procurement process to obtain – among others – relevant information and latest development from market parties on circularity (PIANOo, 2016; Vos, et al., 2019).

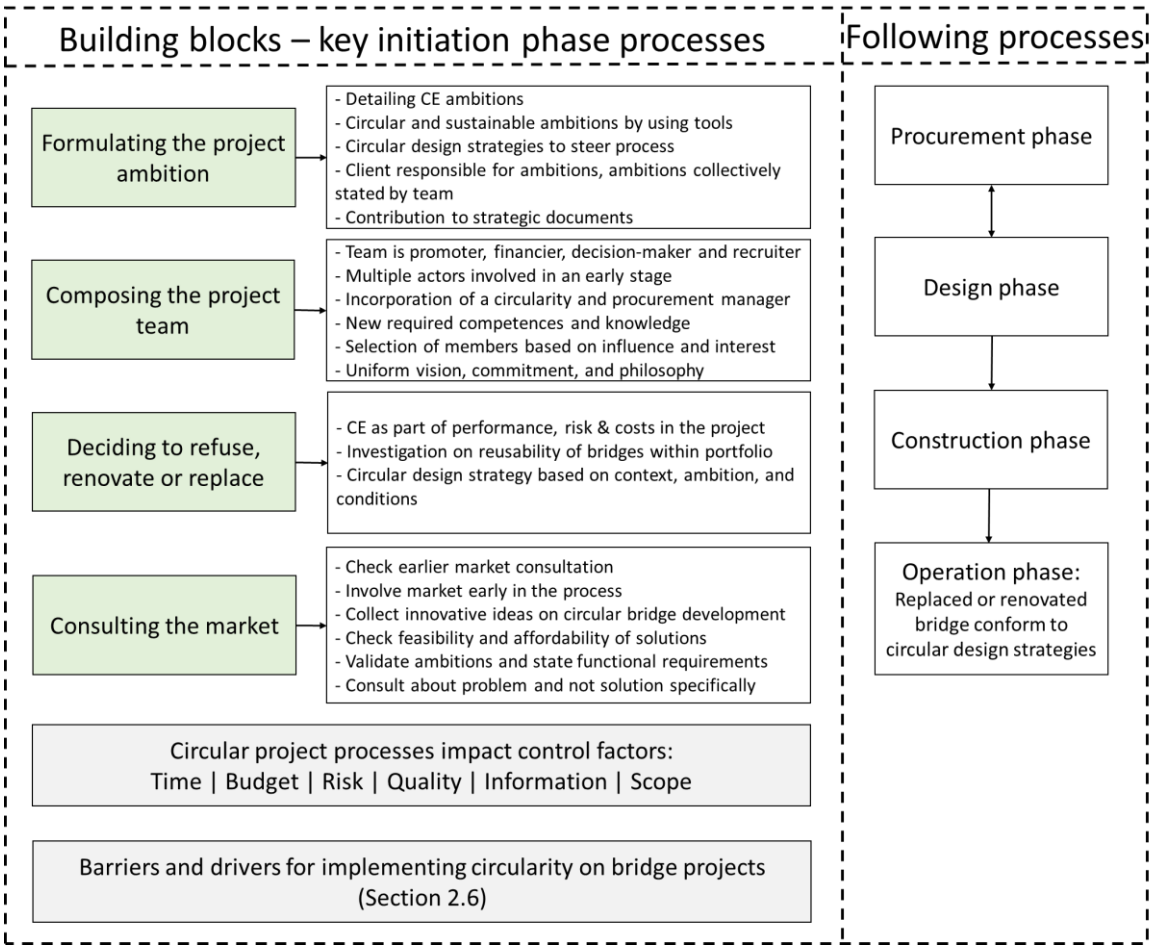

Figure 1 – Framework for circular project processes and phases

So, from the literature review four key processes in the initiation phase are identified that influence the implementation of circularity in bridge development, and can be analysed within the timeframe of this study. These are: 1) formulating the project ambition, 3) composing the project team, 3) deciding to refuse, renovate or replace, and 4) consulting the market. All processes are represented in Figure 1, which form the building blocks for this paper on circular bridge development. Next sections elaborate on these processes.

2.2 Formulating the project ambition

The first core characteristic for circular bridge development is formulating the project ambition as part of the project definition by the client. The importance of the project definition is highlighted by Sanchez & Haas (2018), as they argue that a well-defined project definition corresponds with a higher probability of project success in terms of sustainability. Venselaar et al. (2019) confirm this by stating that detailed described ambitions in the initiation phase form the basis for a circular project. However, there is no consensus on the level of detail of these CE ambitions at the start of a project. The project ambitions are formulated in the project brief (AXELOS, 2017). This document is updated in the next phases.

Further, circular ambitions need to be interpreted in one way (Huijding et al., 2018). Despite that this statement is based on the area development field, it can be understood that this also yields for infrastructure, and thus bridge replacement projects. Another requirement of stating circular ambitions is that these relate to sustainability and circular performance, and ought to be determined using appropriate tools (Platform CB'23, 2021a). Also, circular design strategies of for instance Platform CB'23 (2021a) can be incorporated in the project ambitions to steer the design process later (Leising et al., 2018). Another characteristic of circular ambitions for infrastructure assets, and thus bridges, is that the client is responsible for stating the sustainable ambitions (Platform CB'23, 2021a; Versteeg Conlledo, 2019). Also, literature stresses the importance of multiple internal project members to formulate ambitions to create support for a circular project in e.g. an ambition web session early in the process (Schouten et al., 2022). An ambition web session is a suitable tool because it has specifically been designed for infrastructure projects, and consists of 12 themes including circularity indicators.

In for instance area development projects or MIRT processes, external stakeholders and parties such as residents are often incorporated at the formulation of the project ambition (Huijding et al., 2018; Dijcker et al., 2018). However, this is of less relevance for circular bridge projects, since end-users are often only interested in the functionality (Platform CB'23, 2021a). Despite that, demands and wishes of external stakeholders – for instance water boards and municipalities – still have to be incorporated in the project ambitions. For example, the water board may not want a pillar in their water flow profile, which may exclude circular solutions. A last demand for circular project ambitions is that these are contributing to strategic documents (Appendino et al., 2021; Huijding et al., 2018; Platform CB'23, 2021a). Thus, ambitions contribute to organisational goals, (inter)national goals and policy, regional goals, and should add value for the surroundings (Huijding et al., 2018).

In short, the research derives the following insights from theory:

- Detail ambitions during the initiation phase of the circular project with the internal project team;
- Formulate client ambitions on sustainability and circularity performance with appropriate tools;
- Incorporate circular design strategies to steer the design process;
- State ambitions with multiple internal project members, as the client is responsible for stating the circular ambitions;
- Contribute with ambitions to strategic documents and organisational, (inter)national, and regional sustainability goals.

2.3 Composing the project team

The second core characteristic of circular bridge development is the composition of the project organisation, which is different compared to traditional projects. Project organisations are growing to deal with the large and complex systems to be built (Winch, 2010). It can be argued that the development of a circular bridge is such a complex system, given the multiplicity of aspects involved. The client has responsibilities with respect to mobilising the resource base to achieve the project ambition through the project lifecycle. According to Winch (2010), the client – thus representatives of the province – should

act as a promoter, financier, decision-maker, and recruiter. Especially leadership is stressed for clients in CE projects (Leising et al., 2018). Also, literature suggests that the client pays attention to ensuring CE outcomes at project level (Adams et al., 2017).

Applying circular thinking in the initiation phase can be seen as an innovative process. To implement circularity in construction design, most emphasis in research and guidelines is on the integrated design strategy (Nakajima & Russell, 2014; Platform CB'23, 2021a). The integrated design strategy helps to improve deconstructability, recycling and reuse of components and materials. This can be explained by the presence of multiple actors in an early stage, as these people have a better understanding and awareness of project goals such as circular thinking application (Nakajima & Russell, 2014). Platform CB'23 (2021a) states that traditional roles require new competences in a circular project. These competences lead to new ways of interacting and collaborating. In such a circular project team, it is advised to incorporate a circularity- and procurement manager. Further, literature suggests that these managers monitor circular ambitions, and add knowledge on circularity and business-case conditions (Platform CB'23, 2021a). Regarding the internal project organisation, the team members preferably share the same circular vision, commitment, and philosophy (Versteeg Conlledo, 2019; Kozminska, 2019; Leising et al., 2018). Lastly, literature proposes that the client selects internal project team members of specific departments not only based on experience in bridge construction, but also on their influence and interest with respect to CE (Van Oppen et al., 2018). Together with the level of the circular ambitions, it is the basis for the choice whether in-house capability is present or project resources have to be outsourced (Huijding et al., 2018).

In short, the research derives the following insights from theory:

- Act as a promoter, financier, decision-maker and recruiter;
- Involve actors in an early stage using an integrated design strategy to improve CE performance;
- Incorporate a circularity and procurement manager in the project team;
- Add new competences, such as knowledge on new business-case conditions and circular economy in the team;
- Select internal team members based on their influence, interest and competences needed in a circular project;
- Create a uniform vision, circular commitment, and philosophy within the project team.

2.4 Deciding to refuse, renovate or replace

A core characteristic for circular bridges is the decision to refuse, renovate or replace the bridge. In the linear economy the economic dimensions drive project planning decisions (Sanchez & Haas, 2018). There are few studies on asset management (AM) and/or investment decisions in combination with CE in the construction industry (Rijkswaterstaat, 2015). Also Sanchez & Haas (2018) conclude that early phases of projects lack well-developed methods to 1) decide on replacement and new construction versus adaptive reuse, 2) have proper pre-project planning for circular projects, and 3) plan for the optimisation of the benefits of adaptive reuse instead of building new.

CE principles were implemented in the business case framework for an electricity grid operator as basis for AM decisions (Korse et al., 2016). This would allow for more substantiated AM decision-making. Circularity can have various indicators as no single definition exists. Multi-Criteria Decision Making is desired to assess objectives in projects, since also circularity is often not the only criteria in bridge projects. Tools are needed in an early phase to estimate intangible effects, such as environmental impact. Life cycle analysis (LCA) and material flow analysis (MFA) are tools for the environmental performance. Life cycle costing (LCC), and environmental costs are desired for the economic dimension (Korse et al., 2016). This is about the performance, expenditures, and risk in decision-making (Van Houten & Zhang, 2010). Performance refers to both sustainability, functional, and technical performance. Expenditures are about LCC and environmental costs of for instance CO2 and NOx emissions.

After the decision to renovate or replace a logical step is to find suitable interventions to the bridge. A construction project has a certain context that determines which circular design strategies are feasible (Platform CB'23, 2021a). Together with the project context, the (circular) project ambitions, and conditions to use a strategy, this results in an appropriate circular design strategy. Platform CB'23

(2021a) distinguishes six circular design strategies. Also other strategies are given in literature, such as in the 9R-Framework that prioritises end-of-life strategies from, among which reduce, reuse, recycle, and recover (Potting et al., 2017). Pure application of a design strategy on circular bridge construction is difficult since it needs to be tailored to the specific bridge (Anastasiades et al., 2020; Platform CB'23, 2021a). Also, the decision on how to adopt a certain strategy is a critical decision since these are substantially different to each other in terms of material use and emissions over the lifecycle (Coenen, 2019; Van der Palen & Luijten, 2020).

Regarding the project context, the Bridge Circularity Indicator (BCI) can indicate which circular indicators – reusability, adaptability, design input – are suitable for an objective assessment of bridges specifically (Coenen et al., 2021). Indicators are linked to the expected lifespans. Platform CB'23 (2021a) also highlights the desired lifespan extension in decision-making. Besides that, the BCI framework links the type of spanned area and dynamicity of the area to the circular indicators. So, this framework can also possibly help in deciding on circular design strategies (Coenen et al., 2021).

Standardisation is key in circular bridge construction to effectuate circular design strategies in bridge construction (Anastasiades et al., 2020). It can enable reuse of components (Anastasiades, et al., 2021). Prerequisites to reuse building components are the presence of an economic demand, appropriate routines to disassemble, and performance control until it is integrated in a new structure (Van den Berg et al., 2020). One can imagine that this also yields for bridge constructions. Coenen (2019) adds that bridge components need to have a standard design and should be transportable. Also, reusing bridge (components) requires to meet regulations and norms on – structural – safety (Van Offenbeek-Kuipers et al., 2021). Next to that, Platform CB'23 (2021a) suggests to investigate the asset portfolio of the client to check whether there are potential materials or components that can be used in the bridges. So, AM should know when components need to be replaced, to be able to potentially use them in other projects. The S-layers of Brand (1994) and material passport for bridges specifically are useful here, since it makes clear which components are present, what characteristics they have, and when the components need to be replaced (De Werk, 2020).

In short, the research derives the following insights from theory:

- Incorporate performance, risk, and costs into AM and project decision-making, and translate it into functional performance, sustainability and circularity performance, risk, life cycle costs and environmental costs;
- Investigate whether there are potential materials or components within the portfolio of assets that can be used in the bridge project;
- Choose circular design strategy based on the circular ambition and project context.

2.5 Consulting the market

Public clients contract private parties to design and/or execute the work. Traditionally, the client states a specification, the designer develops a design and the contractor executes the work. However, traditional way of working is not desired when maximizing circularity since roles and collaboration differ (Platform CB'23, 2021a). Instead, intensive cooperation with external parties is needed (Venselaar et al., 2019). In a case where the project scope is not straightforward, public parties may decide to select market parties – like (demolition) contractors and consultants – in an early stage using a market consultation (Van Elburg, 2008). This is especially the case for innovation projects which are unique and are associated with high risks (PIANOo, 2016). Van Oppen et al. (2018) add that for complex products with a long functional life – such as bridges – it is desired to involve suppliers representing different perspectives. Although the market consultation is mentioned as a tool for circular projects and procurement, it is not a prerequisite (Platform CB'23, 2021b).

The general objective of market consultation is to collect innovative ideas from the market, and check the feasibility and affordability of that (Van Elburg, 2008; Vos, et al., 2019). In case of the circular bridge, latest insights on circular development can be asked (PIANOo, 2016). The market consultation is organised by the client, takes place before the tender procedure and can have different formats, such as a closed-, oral-, or written consultation. Before addressing market parties, public clients preferably investigate whether other public clients did a recent market consultation on a same type of project. The usage of their knowledge and experience reduces the time needed to consult market parties, and

reduces the pressure on market parties that bring in knowledge (Vos, et al., 2019). Key point of departure in circular project is that the client can validate and detail their ambition by using the market consultation (Platform CB'23, 2021b; PIANOo, 2016). So, market parties need to be informed about the basic functionality of the product before the consultation, such as bridge characteristics (Van Elburg, 2008). Using the gathered information and insights of the client, the project feasibility and project conditions can be stated. Outcomes of the market consultation procedure can be used directly in the procurement phase (Nagelkerke et al., 2009).

Specifically, using the insight of the market parties, the client can define their Key Performance Indicators (KPIs) – or award criteria – for the circular bridge (Platform CB'23, 2021b). An example would be that the bridge consists of x% renewable materials, or a desired ECI-score (Environmental Cost Indicator). In this way the project ambitions are detailed into clear functional requirements. It is possible to state requirements before the market consultation, however this is not desired because there may be lower support for changes to the requirements within the project team. An advantage is that it is easier to translate requirements into award criteria (PIANOo, 2016). Performing a market consultation before stating the programme of requirements is desired for this project because of choices regarding organisational and project objectives have to be made. In any case, it is key that the client is aware that the consultation is about the problem to be solved, and not the solution to the problem (Vos, et al., 2019).

In short, the research derives the following insights from theory:

- Use results of an earlier similar market consultation, or consult other public clients for results of earlier market consultations;
- Consult external parties in an early phase to put forward multiple perspectives;
- Perform the market consultation to collect innovative ideas from the market;
- Check the feasibility and affordability of the circular plan in the market consultation;
- Validate the project ambition and specify the functional programme of requirements based on the market consultation;
- Focus on the problem to be solved and not directly on the solution to the problem.

2.6 Barriers and enablers for circularity in bridge construction

This section provides additional context on barriers and enablers for circularity in bridge construction. Some of these are also addressed in Section 4 where it is explained how the process takes place in practice, and how and why this is similar or different compared to theory.

Incorporating circularity in the initiation phase of circular bridge (re)construction bring barriers and enablers on multiple domains. Scholars introduced a variety of barriers and enablers for implementing CE industry-wide and in projects (Adams et al., 2017; Hart et al., 2019; Galvão et al., 2018; Coenen, 2022). Hart et al. (2019) showed barriers and enablers by categorising them into four categories: cultural, regulatory, financial, and sectorial. Adams et al. (2017) identified economic, organisational and technical barriers. Especially the organisational barriers are frequently addressed in literature (Charef et al., 2021; Coenen, 2022). This barrier refers – among others – to hindrance in the information flow between stakeholders that negatively impacts the project efficiency in all phases. Also, time, resources and additional effort is needed – in the initiation phase – for the consideration of sustainability and circularity in an object's lifecycle (Charef et al., 2021; Kozminska, 2019). This is related to the required socio-institutional change, which is about reviewing written and unwritten rules, customs and beliefs, and is seen as the greatest challenge in the transition towards CE (Potting et al., 2017). So, this is about laws and regulations, as well as behaviour of actors. Besides that, the lack of structured methods for practitioners is seen as a major barrier in adopting CE in infrastructure projects (Van den Berg et al., 2019; Coenen, 2019; Charef et al., 2021). In addition, insufficient knowledge on CE is a barrier for organisations to adopt CE (Coenen, 2022).

For all organisations, it seems that the lack of incentive to design for the end-of-life is the largest challenge, while long term thinking across the object's lifecycle is required in vision development (Adams et al., 2017). The politics-driven nature of the sector negatively influences the long term vision, which means that there is no room for new solutions that require additional resources, such as time and money (Coenen, 2022). For example, traffic disruption is a driver and barrier for applying CE principles on bridges. Often cheap – low investment costs – and fast designs are selected by clients, which could

work counterproductive for the consideration of all lifecycle phases of the infrastructure asset (Coenen, 2019). However, some circular design strategies could reduce the actual construction time and maintenance periods too (NEN, 2021). Moreover, the lack of market mechanisms to contribute to material recovery and unclear financial case are seen as problematic. As a reaction, a key enabler for circularity in projects is to have a clear business case (Adams et al., 2017).

Focusing on construction clients, the development of a decision-making framework on the entire life cycle is seen as the most important enabler. This can be explained by the high interest of the client in an asset's lifecycle (Adams et al., 2017). Next to that, the client has to provide enabling conditions for collaboration and innovation across the supply chain and the sharing of data (Adams et al., 2017). Working with multidisciplinary teams along the lifecycle is seen as problematic. Therefore, increased access to data is needed to revise the current management of the bridge lifecycle (Charef et al., 2021). Also, the project-based nature and risk-mitigation culture of construction hampers innovation in general. In the short term, lower TRL innovations can help, while on the long term network collaboration with sustainability goals centrally positioned is desired (Coenen, 2022).

With respect to bridge construction itself, a substantial barrier is the existing number of infrastructure that are traditionally built, and where no circularity principles have been adopted (Adams et al., 2017). Technical innovation is not always needed in applying CE principles on infrastructure assets (Potting et al., 2017). However, technical barriers are relevant too (Charef et al., 2021). Specifically for bridges and viaducts, aesthetics and architectural freedom may not be hampered by usage of circularity (Anastasiades et al., 2020). Also, transportability of components for reuse is seen as a barrier (Coenen, 2019). A corresponding enabler is the introduction of standards for design tools (Adams et al., 2017). Further, it is difficult to guarantee the quality of existing components as the CE-assessment is difficult to obtain, new technical norms are not met, and the equivalent quality cannot be assessed easily (Platform CB'23, 2021a). An increasing understanding on assurance and take-back schemes for reused materials would be useful, for instance using the material passport to achieve high-quality reuse (Anastasiades et al., 2020).

This section described theory on processes that take place in the initiation phase of circular development in construction. Traditional project processes and management do not yet consider circularity specifically. Therefore, little is known on how to organise processes and management for circular bridge projects. Despite that in recent years literature made various suggestions on how to organise and perform processes, these studies did not research circular bridge development of bridges that reached their end-of-life specifically.

3 Methodology

This research aims to formulate recommendations for the Province of Overijssel on the organisation of the initiation phase of circular bridge (re)construction by analysing the current process in practice and comparing that with state-of-the-art insights on circular development. A case study research is selected as a suitable research strategy. "The essence of a case study is that it tries to illuminate a decision or set of decisions; why they were taken, how they were implemented, and with what result" (Schramm, 1971, as cited in Yin, 2003, p. 12). This is also the aim in this study, since it intends to analyse two circular bridge (re)construction projects and decisions taken in the initiation phase of this project to explain why decisions were taken to reach a specific result. Case studies often have an explanatory purpose. Data is mainly qualitative given the data collection methods, and there is limited control by the researcher on the case studied, as the case is studied in its natural environment without control of factors. The researcher's involvement is limited, which means that the researcher is detached from the problem to be studied. Case studies collect data in a cross-sectional way which means that data is collected at a specific period and not continuously (Yin, 2003).

3.1 Case study context

The work of Yin (2003) is consulted to determine the suitable case study design. This research is about two cases which are considered as separate projects. Both projects are concrete bridges, however these have their own characteristics and context. For multiple case studies, it is important that cases are carefully selected to show similar results or contradicting results but for predictable reasons. So, multiple case studies follow a replication logic during the investigations. The two individual cases within the

research followed the holistic design. This implies that there is one unit of analysis, which is circular development because the study intends to analyse the way circularity is integrated in the initiation phase in theory, and how this is done – over time – in practice to develop a circular bridge. Together, this makes the *holistic multiple case study* a suitable case study design.

3.2 Cases: Two bridges

A project about renovating two bridges located in the Eastern Netherlands is studied (see Figure 2). Both concrete bridges were built in previous century and are an overpass of a provincial road and two-way cycle path over a waterway. Therefore, these are representative for other bridges that are part of the national renovation- and replacement program in the Netherlands. Bridge I was constructed in 1960. It consists of nine longitudinal beams and one cross beam with nine pillars. The bridge has a length and width of 17.1 and 17.4 meter, respectively. During inspections, defects were observed to the compression layer, columns, and abutments. No as-built information is available for this bridge.

Bridge II was constructed in 1932 and broadened in 1980, it is 27.3 meters long and 14.0 meters wide. Nine longitudinal beams and two cross beams with nine pillars each form the supporting structure. During inspections, damage to the compression layer was observed. That compression layer was strengthened with temporary high-strength concrete. An issue is that the bridge does not meet the most recent water level standards. Both bridges have to be renovated or replaced. Further, the province is interested in sustainability and circularity as it recognises its responsibility to contribute to climate goals. Within the organisation, the circular bridges are seen as a pilot-project.

Figure 2 – Bridge I (left) and Bridge II (right)

3.3 Data collection

Data is collected by using multiple sources with the aim to achieve data triangulation and reduce potential problems with construct validity in the case study (Yin, 2003). In this way, information retrieved using one method can be mirrored to and explained by another method. This increases the understanding of the problem and validity of the research. For the case observations took place by attending one on-site project meeting, five internal project meetings, seven market consultations, and multiple informal conversations with project members. The on-site project meeting took place at the start of this research, where an observation format was used to identify key inputs of team members, determining factors for decisions, the consideration of circularity in these decisions, and related results. For the other meetings, the researcher observed and wrote down key aspects that determined how the process continued and played a role in how and why decisions were made. The researcher attended market consultations to see how the province put it into practice and worked with market parties. Also, market parties introduced valuable insights that public clients should consider in their initiation phase. Observing the meetings was relevant to discover how and why decisions on the process were made considering project management aspects and barriers for circularity.

Besides observations, semi-structured interviews are conducted with ten project team members, as a method to derive a large set of qualitative data to generate evidence (Green et al., 2007). The roles of the interviewees were programme manager; project leader; contract manager; contract advisor; procurement advisor; expert innovative procurement; structural engineer; technical manager; realisation supervisor; and stakeholder manager. Except for the programme manager, the project members are part of the core project team and were involved in the initiation phase of the project. Therefore, these interviewees could explain how and why processes took place. The programme manager was interviewed because of the role as internal client, and circularity initiator of the project. Interview questions directly followed from the identified key characteristics of circular bridge construction. Besides

that, the interview included follow-up questions that revealed barriers, enablers, and conditions on embedding circularity in the construction process. Thereafter, summarised transcription is used for the interviews to interpret answers directly. However, summarised transcription is less objective compared to full transcription (Verschuren & Doorewaard, 2010). Therefore, the concerned interviewee reviewed the transcript. Citations of interviews and observations are shown in the results, tables, and appendices as exemplary evidence.

The third data collection method is document analysis, which has an important role in case study data collection, as these contain valuable information that is permanently available and can be reanalysed (Yin, 2003). Documentation types used are the project brief, project plan, as-built information, meeting notes and brainstorm flyovers. From the project brief and project plan, the researcher obtained information on how the project was initially initiated, before the researcher started the study. As-built information helped to understand how the bridges were constructed, and how the drawings contribute to certain project decisions, such as the choice for suitable measures on structural safety. Lastly, using meeting notes and brainstorm flyovers helped to check own interpretation of the meeting results with the actual meeting notes. Next to that, the documents made it possible to see how project decisions and processes follow-up or change over time. By immediately interpreting results of all data collection methods, tentative recommendations are formulated in the results section.

Finally, a panel discussion was organised with the project team which validated the potential and feasibility of tentative recommendations that follow from empirical and theoretical findings. During the panel discussion, where six project team members involved at the cases were present, the researcher introduced main tentative recommendations in terms of statements and a brief explanation on the specific recommendations. Then, the project team voted via hand raising to agree or disagree on the tentative recommendations. After that, there was the possibility for attendees to react on each recommendation by the project team. The results of the panel discussion are presented in a validation format. The results of the panel discussion are also used to describe the potential of the recommendations (see Appendix A-D). This is done by adding a high, medium, or low potential, including a brief explanation.

3.4 Data analysis

For the analysis of data and to eventually achieve the research objective, a pattern matching research strategy was selected. Pattern matching is one of the most desirable techniques for qualitative analysis and case studies (Trochim, 1989; Yin, 2003). Trochim (1989, p. 356) defines a pattern as “any arrangement of objects or entities”, which means that patterns are describable and non-random. A pattern matching research is about linking two patterns: a theoretical and observed pattern. The observed pattern is also known as an operational pattern or empirical pattern (Trochim, 1989; Cao et al., 2004).

The pattern matching process consists of three steps. The first step is to specify a theoretical pattern (Section 2) based on theories and ideas. In the second step the empirical pattern (Section 4) is obtained using data collection methods (Section 3.3). The third step is the attempt to match the theoretical pattern and empirical pattern (Trochim, 1989). So, it compares the so-called ‘pragmatic reality’ with ‘theoretical ideals’ to subsequently investigate similarities and differences between the two patterns. To make it more explicit, *what is done* is compared with *what ought to be done*. Doing so, it enhances the critical understanding and learning of a specific pattern (Cao et al., 2004). In this research the empirical and theoretical pattern are compared in terms of four core characteristics of integrating circularity in projects: 1) formulating the ambitions, 2) composing the project team, 3) deciding to renovate or replace, and 4) consulting the market.

The conclusions of pattern matching take two directions given the fact that theory and practice are compared. On the one hand, if the pragmatic reality matches the theoretical ideal, then the theory can be used to explain the reality. This strengthens the validity of the theory and practice. On the other hand, if the pragmatic reality and theoretical ideal differ, then these differences are useful to develop new ideas and concepts in theory as well as in practice (Cao et al., 2004). Therefore, reflection on and understanding of patterns is needed to justify conclusions on differences and similarities. Recently, studies within the field of strategic urban planning and virtual reality in construction design used pattern

matching as research strategy as well (De Graaf & Dewulf, 2010; Van den Berg et al., 2017). To determine a match in this research, the theoretical pattern must be observed in the project meeting, observations, or project documentation by the researcher, or the topic is addressed in 7-10 interviews. A partial match means that the theoretical pattern is partly observed, or addressed in 4-6 interviews. No match implies that the theoretical pattern was not observed in practice, or addressed in 1-3 interviews.

Finally, recommendations for the province are formulated that can potentially be used in future bridge projects, based on the similarities and differences that follow from the theoretical and empirical pattern using the data collection methods. Interviews resulted in a large set of qualitative data that showed a variety of insights on the four patterns. All the interview questions are based on the underlying theoretical insights of the patterns. Then, during analysing the summarised transcripts, the answers for each research questions are grouped based on comparable answers that explain the research question, which form the basis for explaining the empirical pattern in relation to the theoretical pattern. An example is the influence of the factor time in stating a circular ambition. Then, these insights are transformed into recommendations for each pattern. Sometimes questions could not be answered by certain interviewees, while others could because of their expertise. In that case, more attention is paid to the answer of the concerned expert to make the step towards recommendations. Using the panel discussion, tentative recommendations are translated into final insights in combination with existing literature. The implications of similarities and differences form the basis for the recommendations. Appendix E shows a (clickable) guideline that summarises the findings and recommendation on when to do a process, what to do, and under which conditions. The research model is schematised in Figure 3.

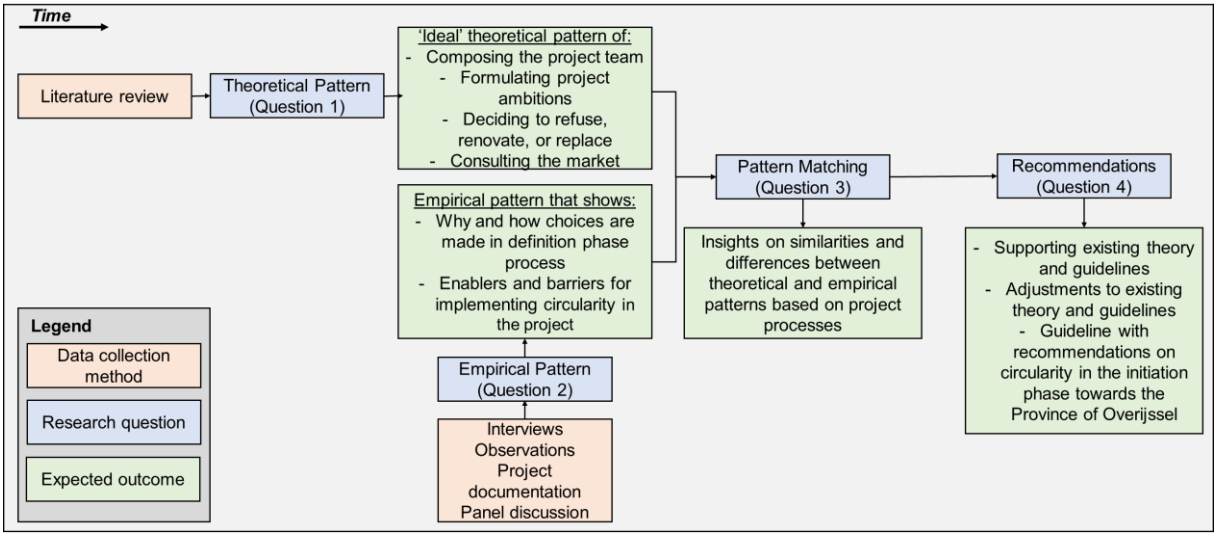

Figure 3 – Research model visualisation

4 Results

This section describes the findings of the two real-world cases from which an empirical pattern is derived in terms of four core characteristics of circularity in the initiation phase of circular development. The comparison of patterns is also shown in tables at the end of each section, and an extended version is shown in Appendix A-D. The suitability of the organisational project management system is discussed first, before elaborating on the specific processes that take place within the system.

Among project members, the internal project management steps are seen as suitable for circular projects, mainly because of the structure it provides in the project. However, multiple team members argued that it is not about the steps specifically, but about the meaning and implementation of processes within these steps. The contract advisor explained: “All choices – on policy, asset management, programme, and project level – should be made based on the 9R-framework, this does not happen right now, … What we often do is that we choose a lower R compared to what we are doing now, instead of starting at the top of the 9R-framekwork.” Therefore, compared to linear projects, circular projects push

the boundaries of existing project management systems, as these are not in line with the concept of circular economy.

For both bridges, a time-consuming initiation phase took place to find the best solutions for the projects given the fact that circularity was not well-understood by the project organisation. However, the initiation and subsequent phases overlapped since the need for circularity became more important in the project compared to project initiation. Also, the impact of circularity on the project was underestimated by the project initiator, as the project brief included a predetermined project scope for the preparation and execution.

4.1 Empirical pattern 1: Formulating the project ambition

The first empirical pattern is about the formulation of the client's circular project ambition, which matches partly with theory. For both bridges ambitions were broadly formulated in the project brief by mentioning sustainability and circularity terms of 'aiming at improving' it, and referring to ambitions on strategic level. Next to that, TCO minimisation and the applicability of industrial, flexible, and demountable (IFD) bridge construction had to be investigated as possible solution. The analysis found an explanation for this. There was no organisational vision on how to approach circularity in projects, and it was underestimated how the need for circular bridges influences the initiation phase in terms of time needed for discussions. Also, the nature of stating ambitions at the start of the project resulted in a difference in commitment among team members to design based on circular economy principles. Since circular ambitions were not stressed, some team members argued that these should be left out because these were not demanded by the internal client (programme manager). Notable is that there is one ambition for two projects, whereas Bridge I and Bridge II differ in terms of their context, such as structural condition and water level requirements. The reason being is that additional investigations on the bridges' structural safety took place during the initiation phase that changed the project.

Regarding detailing the ambitions, which did not match with theory, an extensive and time-consuming process took place. Ambitions are detailed into objectives after consulting market parties, while at the same time the definitive decision on replacement or strengthening had to be made by the project team. The analysis found explanations for this. First, no circular ambitions on asset management level resulted in a lack of steering from higher-order circularity goals in the project, implying that operational objectives had to be stated by the project team, while there were no objectives on tactical level in the organisation. Secondly, the inexperienced project team searched for opportunities, and viewed the project as a learning-trajectory. During the on-site project meeting, project members introduced their view on circularity, as they argued: "We want a low-maintenance bridge … We want to investigate the possibilities for an IFD bridge … We have to make clear what we actually want". These quotes illustrate the difficulty on the meaning of circularity and the circular ambition. This unclarity and non-uniform vision was present during the project start, and hardly reduced during project continuation.

Regarding the incorporation of circular design strategies to steer the process, practice does not match theory. The project team did not reach consensus on what to do with the bridges, even though the project brief stated to investigate the possibilities for IFD construction. Project members argued that IFD construction in the project brief resulted from the fact that the organisation participated in a working group on IFD construction and national technical norm development. However, the project team viewed all options on circular bridge development given the lack of organisational ambitions and doubts on the suitability of IFD construction for one-off projects. At this circular knowledge level and unfamiliarity with circular solutions, the proposed IFD construction resulted in consternation instead of clarity. One of the project team members argued that in the future both programme and asset management should make an early choice on circularity in projects, based on lessons-learned in this project. For example, the need for secondary components, adaptability, or desired lifespan in accordance with expected use should be clear before the project brief. This indirectly provides direction towards circular design strategies.

About stating project ambitions, the internal organisation and project team felt responsible. Therefore, theory and practice match. However, because of the lack of organisational vision, knowledge, experience on circularity, and different commitment by team members, the project team was not able to formulate ambitions by themselves. Instead, the project needed market parties to concretise ambitions. The core project team of the province formulated ambitions collectively in a session using results of the

market consultations to subsequently define objectives for the project that required approval by programme management. So, top-down support is required. Remarkably, no ambition web session took place to define the project ambitions, while project members viewed it as a useful tool. However, interviews also revealed that the ambition web session may result in similar results for comparable projects, which reduces the usefulness of the tool on project-level.

Regarding the contribution of project ambitions to strategic documents, which is the basis for circular development, the ambitions in the project brief and formulated during the process contributed to strategic goals. Examples are national reduction targets, and the Regional Transition Agenda Infrastructure by the province, which states to be 50% and 100% circular in 2030 and 2050, respectively. However, there is no formulation of tactical – asset management and programme level – goals. The programme manager explained the situation: "What is happening is that there are strategic goals, however the translation towards tactical and thereafter operational goals has to be made within the organisation. At the same time, a circular project is going on, while there are no tactical and operational goals formulated. This results in difficulties in the project." So, the unclear meaning of circularity and lack of concrete circularity goals on tactical level result in difficulties on project level. Despite that referring to strategic goals do initialise a circular project, it does not provide guidance on ambitions in the initiation phase of circular projects. A summary of all comparisons is shown in Table 1.

Summary

For stating the ambition, the lack of circular ambitions on tactical level is seen as a substantial barrier in the process of stating ambitions and detailing them towards objectives. Based on the data collected, two suggestions are made to potentially ease the process of formulating circular project ambitions. First, state ambitions on asset management level within the AM-plan. The 80/20 rule could be used here, 80% of the ambitions on asset level, and 20% can be adjusted and sharpened based on the project context. A suitable tool to state ambitions collectively is the ambition web. The ambition web can take place for each asset category because the experience is that ambition sessions cost time, and produce nearly similar results for same asset categories. Second, in case the tactical level vision is not clear, ambitions can be stated on project-level and should be reused for future projects. However, project members argued that top-down support is required.

Table 1 – Summarised patterns compared: Formulating the project ambition

Theoretical insight	Empirical finding	Exemplary evidence	Match
Detail ambitions during the initiation phase of the circular project with the internal project team.	Detailing ambitions was complex due to the lack of asset management and circular ambitions and objectives on tactical level.	"CE objectives is an organisational policy issue, we are ahead of that,…, the province needs a vision on circularity in infrastructure that helps us" (Project meeting, 30-5).	Partly
Formulate client ambitions on sustainability and circularity performance with appropriate tools.	Circular and sustainable ambitions are stated on strategic level, and these mention the need to investigate IFD construction. No tools are used by the project team or programme management.	"TCO should be minimised and improvement with respect to sustainability, circularity and climate adaptation" (Project documentation). "Investigate whether NTA8085 – IFD construction is applicable for this project" (Project documentation).	No
Incorporate circular design strategies to steer the design process.	Despite that the suitability of IFD construction had to be investigated according to the project brief, no circular design strategies were specifically documented.	"No strategies are used beforehand because both the organisation and project is in a pilot-phase" (Interview 4).	Partly
State ambitions with multiple internal project members, as the client is responsible for stating the circular ambitions.	The core project team formulated ambitions during the initiation phase based on information gained by market parties.	A session to define objectives took place on 23-5 and 30-5 with the core project team using a presentation and discussion on what was learned by information from market parties.	Yes
Contribute with ambitions to strategic documents and organisational, (inter)national, and regional sustainability goals.	Ambitions contribute to strategic goals, which are the national goals by the Ministry, the Regional Transition Agenda by the Province, and the AM plan of the organisation.	Project documentation states strategic goals by referring to 50% and 100% circular in 2030 and 2050, respectively.	Yes

4.2 Empirical pattern 2: Composing the project team

Regarding the project team acting as a promotor, financier, decision-maker and recruiter, practice does match theory, however to varying degrees. For both bridges the project team acted as a promoter to develop the new bridge while incorporating circularity. However, the development of the bridge delayed due to the focus on circularity and discussions on how to approach circularity for the context. The project leader managed the available budget for financing the project. However, the project leader and team perceived the budget as insufficient because it was estimated on 'traditional' bridge replacement, and

not indexed towards the most recent price level. The project team decided on how to continue the project, examples are the need for additional investigations on structural safety, and how to transform the general ambitions into objectives on operational level. However, observations revealed that decision-making was hard because of the unstructured way of decision-making, the lack of information and knowledge at the moment of decision-making, inexperience, and lack of tactical-level CE ambitions. Further, the interviews showed that the project team recruits market parties by consulting them early in the process, which helped to gain required information and formulate project-level ambitions.

With respect to an integrated design strategy with multiple actors involved in an early stage, all core project members attended the initiation phase. Therefore, empirical findings match theory. To have multiple expertise present from the start of the project, the project leader used an integrated project (IPM) team approach. However, team members argued that the team is large for the scale of the project. On the one hand, this helped in assessing opportunities in the project. On the other hand, decision-making is harder and more time-consuming given the different perspectives of the involved roles. Besides that, team members argued that the size of the project team is too expensive for future projects. There was no difference in presence of team members for Bridge I and Bridge II.

Regarding the need for a procurement and circularity manager, which is considered as necessary in circular projects, empirical findings partly match theory. A procurement advisor attended the initiation phase. Both procurement advisor and contract manager are desired to include in the initiation phase, as the contract manager explained: “Contract managers, contract advisors, and procurement advisors should be present at the project initiation, before the project brief for realisation and contract preparation is developed, mainly because in the project brief often choices are already made which influence the procurement strategy. Next to that, choices that need investigation need proper explanation on why a decision is made”. So, these are informative roles that are involved in decision-making based on their expertise. Members also argued that the extent of involvement is project-dependent, for the case bridges there was no distinction in the extent advisors are involved.

However, no circularity manager – or expert – was incorporated in the initiation phase. First, interviewees argued that a circularity expert would go towards a level of detail that is not desired in the initiation phase. Second, a project member argued that a circularity expert is not needed because an expert makes decisions, which should be made by the team and project leader ultimately. Instead, an advisor would be more appropriate. Moreover, there was the presence of an expert innovative procurement, who boosted the circular implementation process. However, no concrete advises on bridge development in relation to circularity could be given due to the lack of technical knowledge on bridges. Five of the ten team members agreed on the fact that a circularity advisor should be incorporated in the future, who has a niche of expertise on for instance Environmental Cost Indicator (ECI, or *NL: MKI*) calculations. According to the procurement advisor, ECI becomes mainstream in civil engineering, which increases the need for an internal expert on that. Currently, no internal expert with both circular, as well as specialised knowledge is available. This person can be outsourced, however one of the interviews showed that internal knowledge is needed to assess the work of an outsourced consultant. Lastly, team members that disagreed argued that a circularity expert is redundant if circular objectives on tactical level are clear.

The need for new competences and knowledge in circular projects partially matches theory. The analysis showed that there were new competences available due to the introduction of the procurement advisors in the initiation phase. These introduced innovative forms of procurement and steered the process to find the right objectives to assess alternatives upon. The analysis revealed by observations that the project included no major new competences, while it was argued by project team members that the project is different compared to traditional projects. In the interviews, nine of the ten project members agreed on the fact that the project needs new competences and knowledge. Though, most members also argued that new competences are not necessarily needed whereas knowledge is. Knowledge on innovative forms of procurement was present. The team incorporated technical expertise and management capabilities, however the team included no knowledge on circularity in construction projects. The researcher noticed that none of the project members developed a circular bridge before. Team members mentioned a key barrier for the lack of knowledge within the organisation. Continuous

improvement – PDCA – is hampered due to the large amounts of temporary contracts. Employees leave the organisation after a project is finished, which results in a knowledge loss.

The selection of project members, preferably based on their influence, interest, and competences partly match theory. Again, the project team included procurement advisors because of their knowledge and interest in innovative procurement and innovation projects. Experience with circularity did not play a major role in selecting team members, because of the limited experience within the infrastructure department. Three team members argued that knowledge may be present within the province, however it may be unknown among employees that this knowledge is present in other departments of the province. So, knowledge has to be facilitated and organised internally. Moreover, interviews showed that the extensive initiation phase of the circular bridge project require new competences to detail an unclear project scope that also requires circularity. Therefore, multiple team members argued to select a project leader based on the competences needed for the initiation phase of circular projects. This phase has no detailed scope and requires an analysis of circular possibilities. Therefore, interviews revealed that the project leader should not dive towards solutions immediately, but understand different solutions and be decisive on what solution is most suitable for the project.

Practice does not match theory regarding the desired uniform vision, circular commitment, and philosophy of the project team. Project members did not have a uniform vision. This can be explained by the lack of steering from ambition form asset management, the lack of experience and knowledge of employees, and the different perceptions on the meaning of circularity and sustainability. About commitment, a substantial difference could be observed at the start of the project due to the different expectations among team members on the circular project. Especially the project brief was the cause of different commitment, since the ambition ‘investigate the possibilities for IFD construction’ was interpreted differently in terms of how extensive it should be investigated. Also, project members perceived circularity as a treat to finish the project within the predetermined budget and time, mainly due to the predetermined scope of the project. As a result, circularity is key for some members, whereas for others it is a wish. However, interviews also showed that a broad-formulated project ambition can stimulate the process in case the knowledge level is higher, and the project scope – mainly time period – is not stated yet. Circular commitment increased among project members during the process and especially after the market consultation, because it became more clear what was, and what was not possible regarding circular bridge construction within the predetermined scope. All in all, interviews showed that commitment is a key informal project factor with large influence on the success of circular development. A summary of all comparisons is shown in Table 2.

Summary

There are mixed views by the project members on the project team. In general, interviewees agreed on the need for new knowledge within the internal project team. Besides that, competences are also needed, but received less attention by interviewees. Further, the uniform circular vision, commitment and philosophy of the project team is desired, but hampered by a number of factors.

Based on that, the research suggests to include professional knowledge in combination with circular knowledge, or hire specialised knowledge. Also, incorporating a procurement advisor, contract advisor, and circularity advisor is desired. These have an informative role and are consulted when needed by the project leader. This has the advantage to limit the costs of the project team, while at the same time having the structure of an IPM-team. Regarding achieving a more uniform vision and commitment, it is important to discuss the meaning of circularity for the project context. The earlier-introduced ambition web session could be useful here, even as the role of the project leader to achieve circular commitment in the team.

Table 2 – Summarised patterns compared: Composing the project team

Theoretical insight	Empirical finding	Exemplary evidence	Match
Act as a promoter, financier, decision-maker and recruiter.	The project team promotes because the need for a new bridge is clear, finances the project with available budget, makes decisions for project continuation, and recruits market parties to be able to state ambitions.	Observed by researcher during project meetings.	Yes
Involve actors in an early stage using an integrated design strategy to improve CE performance.	A large IPM team is set-up where multiple disciplines are present and put forward information based on their expertise.	"This team is a relatively large IPM team given the nature (budget and scope) of the project" (Conversation, 30-3). "Future project teams need to be lean" (Conversation, 27-6).	Yes
Incorporate a circularity and procurement manager in the project team.	The project involved a procurement advisor and expert on innovative procurement. It did not involve a circularity manager or expert.	"This project is different in the way that an expert innovative procurement and procurement advisor are present for creating an innovative environment and circular project result" (Conversation, 3-4). "The internal employee on circularity was not involved because the project would go too fast into details" (Conversation, 30-5).	Partly
Add new competences, such as knowledge on new business-case conditions and circular economy in the team.	Knowledge on innovative forms of procurement is present. These people also bring new competences. However, no in-depth knowledge is present on circularity in combination with existing expertise.	"Internal team members should be up-to-date with state-of-the-art circular developments, especially the project leader because he is in the lead, this is not the case now" (Interview 7).	Partly
Select internal team members based on their influence, interest and competences needed in a circular project.	A procurement advisor and expert innovative procurement were incorporated because of the need for circularity in the project. There was no specific method for composing the project team.	"Experience with circularity is not used to find the right team members, also because there is marginal experience within the province" (Interview 1).	Partly
Create a uniform vision, circular commitment, and philosophy within the project team.	There was substantial difference in vision and commitment towards circular solutions and collaboration forms. After the market consultation commitment increased and converged between team members.	"What goes well is the increasing involvement and the will, project members to apply circularity in the project" (Interview 3). "The openness for circular solutions grew during the project due to the information from the market, while initially the purpose market consultation was not well-understood" (Interview 6).	No

4.3 Empirical pattern 3: Deciding to refuse, renovate or replace

Regarding the implementation of circularity in performance, risk, and expenditures for AM decisions, findings do not match with theory. A project meeting showed that the decision to start measures on the bridge resulted from the expected lower functional performance, and the safety in terms of structural performance. Therefore, the AM decision is a yes or no decision to start a project based on performance and corresponding risk. These are key factors to start a project, since the AM-plan aims at maintaining the functionality and safety of their bridges. According to the asset manager, to incorporate sustainability in AM decisions, internal knowledge is needed on LCA, which is currently not in-house.

Subsequently, an investigation on replacement or strengthening of the bridges took place in the initiation phase, which considered performance in terms future functionality, risk in terms of safety. Costs was not yet an issue, however it was stated that if the costs of strengthening outweigh replacement, then replacement will take place. No explicit circularity assessment took place during the decision to replace or strengthen the bridges. However, the project leader argued: "We achieve already a higher level of circularity when the bridge is being strengthened by reusing the substructure, instead of replaced completely". So, strengthening is a circular option according to the project leader given the material and waste reduction.

As a result, Bridge I had to be replaced and Bridge II strengthened, whereas initially both bridges would be replaced because of risk mitigation behaviour of the project team. This decision is based on an initial visual inspection, recalculation on the load bearing capacity based on original construction drawings, and a concrete study. The decision to strengthen was made later in the project, as based on beforementioned information it became clear during the project that the bridge could be strengthened for the desired lifespan extension, whereas it was not in the asset management process. However, the programme manager argued: "I think it is the wrong sequence if the decision to renovate or replace is made within the project". The interviews confirmed to make the decision during asset management, and not during the project itself, as these interviews showed the conflict between the predetermined scope and time needed for additional research on strengthening. Also, budgeting may be inaccurate if the measure is not clear before the project start, which is problematic for long term programming. However,

interviews showed that it is possible to make the decision in the project, provided that an extended initiation phase takes place, without a predetermined scope.

Regarding the investigation on reusability of the bridge (components), practice does match theory. The project team investigated the possibility to reuse existing bridges, but Bridge I could not be reused with the same functionality because of insufficient information on the structural safety. As a result, material recycling is likely to take place. The substructure of Bridge II is reused at the same location, whereas the compression layer, as part of the superstructure, is strengthened. So, material characteristics, structural safety and related risks were key in determining the level of reusability of bridge components. Reusing components of other bridges was not an option, because there were no pre-planned bridges that also had to be replaced, which means that there was no available supply.

Practice does not match theory regarding the decision on a circular design strategy based on ambition and project context. There was no structured plan to choose the circular design strategy. The project team learned during the process about advantages and disadvantages of specific circular design strategies, but they were not aware of for instance the indicators stated in the BCI, and relative importance of project factors in relation to circular indicators. The project team aimed at making the decision based on the ambition for the bridges, however, again, given the lack of tactical level ambition and knowledge, no substantiated choice was made. According to team members, no organisational circular vision is problematic, since continuity with respect to circular solutions for bridges is required to stimulate innovations, and achieving economies of scale that enhances the possibility for standardisation and interchanging components. A summary of all comparisons is shown in Table 3.

Summary

Observations and interviews showed the difficulties that the project team experienced during the decision to refuse, renovate or replace. Based on the empirical findings, the research suggests to integrate circularity in the performance, risk, and cost assessment. This can be done by translating performance into functional, technical, and circular performance, and costs into life cycle costs and environmental costs. While doing so, the expected lifespan is desired to be considered. The moment of decision-making has two directions, on the one hand in the initiation phase of the project, without having a clear project scope. On the other hand, during the asset management phase, to be able to have a more clear project scope, and more accurate budget estimation by programme management. Third, to reuse bridge components, or components within the portfolio, long term planning is advised to programme bridge replacements.

Table 3 – Summarised patterns compared: Deciding to renovate or replace

Theoretical insight	Empirical finding	Exemplary evidence	Match
Incorporate performance, risk, and costs into AM and project decision-making, and translate it into functional performance, sustainability and circularity performance, risk, life cycle costs and environmental costs.	The AM decision was based on the high risk with regard to structural safety in the coming years. As a result it was questionable whether the functional performance of the bridge would suffice in the next years. Costs did not play a major role. However, costs play a major role in deciding to renovate or replace. No sustainability and circularity factors were incorporated in the decision-making.	"When the costs to strengthen the bridge outweigh the costs for replacing it, then the bridge will be replaced" (Project meeting 8-3). "Bridge I is replaced because of the risk, as it is uncertain what the structural condition of the bridge is" (Conversation 11-4). "Bridge II is strengthened because the structural performance has shown to be sufficient for the current traffic load, provided that the concrete check is sufficient too" (Conversation 11-4).	No
Investigate whether there are potential materials or components within the portfolio of assets that can be used in the bridge project.	Investigated, but no components were available within assets of the province and other provinces within the timeframe. Components of case bridges could not be reused on the same functionality due to the material performance.	"We should know in advance when bridges (of other public clients) become available, this is not the case in this project" (Conversation 15-6).	Yes
Choose circular design strategy based on the circular ambition and project context.	The relation for suitable circular indicators and circular design strategies for the project context were not well-understood by the project team because of the lack of experience with, and knowledge on, circular projects.	"At the moment there is no substantiated method to make the choice, also because there is no organisational vision, the project team does what they think is the best option,… performance, risk and costs, are suitable to make decision on solution types and to use that decision for future projects" (Interview 2).	No

4.4 Empirical pattern 4: Consulting the market

The analysis of the initiation phase of circular bridge development revealed that gaining knowledge from the market was the main purpose of the market consultation as knowledge was not in-house. As a result of that, project objectives were developed. Among the project team members, the market consultation was therefore viewed as a useful tool for the current knowledge level on circularity within the organisation. However, market consultations are not mandatory for circular projects. Therefore, this study also explored whether future circular bridge projects require market consultations.

Team members agree because they argue that it is needed to stay up to date with latest developments of market parties. However, they recognise that a large market consultation is not desired because of the time needed. Instead, a more specific – or mini-market consultation – would be useful to stay up to date with latest developments on for instance cement-free concrete beams. Overall, interviews revealed that the market consultation should only be performed in case of insufficient information or knowledge. The team members that scored neutral argued that consultations are needed because innovations and solutions change rapidly. Simultaneously, they add that is not needed when working circular is standard within the organisation. Multiple arguments were given by team members on why not to perform a market consultation in the future. First, information is retrieved from market without a monetary compensation, while answering the questions from the client is time-consuming. Consequently, not all information may be shared in-depth by market parties. Second, the programme manager explained that: “A market consultation is about gaining information of the market by consulting them instead of intensively cooperating with them, while cooperation is desired for circular projects”. Thus, market consultations tend to be a one-way information collection, instead of intensive cooperation. The procurement advisor adds to the two arguments against a market consultation that: “It should not be the case that we educate ourselves using the market consultation”. So, one should be careful by collecting one-way information in market consultation, where market parties spend significant amount of time on answering questions without obtaining a monetary compensation. Third, a market consultation is also time-consuming for clients. Therefore, team members argued that it is not needed for the next years for similar projects. Fourth, there are other options to collaborate or consult the market. Examples are the competitive dialogue, design team agreement, market exploration, informal meetings, symposia, phone calls, etc. Last, an interviewee proposed to procure an innovation that is potentially useful for the province, without assigning a specific project. This innovation can be used later and further developed in future projects.

Regarding the usage of earlier performed consultations to reduce pressure on market parties, no matching score is assigned because no market consultation was performed before on circular bridges. Reusing information is especially relevant for the current tight labour market, as recognised by the project team. The project team realised that the large market consultation to gain information on circular bridge development will not be effective for similar projects in the near future. This is mainly because of the time market parties must invest, and the probability that the same answers will be given. Instead of using results of previous consultations, a meeting with another decentral government was organised to gain information and experience on a circular bridge they built.

The early involvement of parties match theory due to the use of the market consultation. Contractors and consultancies participated in the market consultation. Selection of parties was based on the experience with innovations in bridge construction and/or their involvement in working groups on circular bridges. Selected parties could replace Bridge I or strengthen Bridge II. Then, parties received a questionnaire with questions from the province, which they answered. Subsequently, the project team selected parties based on their answers, which they viewed as potentially useful for the project. Demolition contractors and suppliers were not involved in the market consultation as these would not have the desired information on constructing bridges. However, these will probably be involved early by using a design team agreement, as observations by the researcher during project team meetings showed that the team is aware of the importance to involve demolition contractors early in the project.

Regarding the collection of innovative ideas, practice and theory match. The consultation was performed to collect innovative ideas for the cases. However, innovations were limited to a TRL 8 or 9, implying that the solution must be tested and validated under operational use, or ready for deployment. The interviews showed that risk aversion of the organisation, and the unfamiliarity of the project team with circular solutions were main reasons for the desired TRL’s. The technical manager explained this based

on his experience: “In another project sheet piles could be reused, however the province did not want to bear the risk concerning the structural performance in relation to the required lifespan. This is a risk that a contractor cannot bear. The possibility for circular sheet piles is therefore not utilised.” So, risk aversion of clients may limit the possibilities for circular innovation.

The feasibility and affordability of circular solutions and collaboration forms for bridge replacement and strengthening are addressed in the market consultation. Therefore, practice does match theory. The consultation was extensive because of the considerable number and variety of questions from the province to the market parties. This can be explained by the lack of an organisational vision, so the feasibility and affordability of specific solutions and collaboration forms could not be asked. Instead, multiple solutions including cost estimation were addressed, such as reusing concrete beams, IFD-construction for Bridge I, or strengthening with bio-composites for Bridge II.

Practice partially does not match theory regarding the validation of project ambitions and formulation of the programme of requirements. As mentioned, the market consultation took place to gain insights into the latest development in circular bridge development. According to team members, validating the project ambition can only be done at a higher level of detail, and a more detailed vision where the feasibility of solutions in relation to the vision can be discussed. Since this is not the case, the ambition was formed after the consultation. The interviews revealed that an ambition before the market consultation may result in the exclusion of solutions. Ideally, when asset management ambitions are clear, a more detailed market consultation can take place to make the choice based on the state-of-the-art solutions in the market that are in line with the objectives.

Regarding the focus of the market consultation on the problem to be solved, instead of on solutions, theory matches practice. This was clearly the case as diverging of solutions took place. Based on the ambitions formed using the market consultation, objectives were stated that were most suitable for the project according to the project team, so converging of gained information took place. Solutions proposed by the market parties are subject to the concept of vendor lock-in, as every contractor has its own product that it wants to sell. The project team experienced the vendor lock-in as the structural engineer explained: “Sustainability and circularity is desired by every party. There are multiple solutions to construct circular. The most ideal solution is a mix of multiple solutions, however these solutions are shielded by the commercial interest of contractors”. The project team argued in the interviews and project meetings that they do not want to be dependent on one supplier in the renovation and replacement programme. So, at this moment standardisation occurs on company-level. This results in a lock-in on for instance interfaces for bridge elements, which impedes interchanging bridges components of different contractors. The experienced vendor lock-in stresses the need for norms. A summary of all comparisons is shown in Table 4.

Summary

In short, there are mixed views on the (future) usage of market consultations for circular projects. The main reason for performing a consultation is because there is insufficient knowledge and information within the client organisation. Also, keeping up to date with market developments is a key factor. Reasons for not doing a market consultation are the missing monetary compensation for market parties and the time that is asked from market parties.

Based on the empirical findings suggestions are made. First, a market consultation is desired in case the internal knowledge level is insufficient, and no market consultation has been performed. However, multiple other options exist to gain data and collaborate with market parties. Second, sharing of market consultation results between public clients is desired because of the many consultations done, which are not shared. Third, this research suggests performing market consultation on asset categories and update these frequently to have state-of-the-art ambitions. Updating can be done based on for instance knowledge that internal employees gained during previous projects. Fourth, a lower TRL is desired for short-term innovation. However, risk aversion of the province is a substantial barrier. For long term innovation, network collaboration is suggested to further develop innovations by procuring similar solution types based on the organisational vision.

Table 4 – Summarised patterns compared: Consulting the market

Theoretical insight	Empirical finding	Exemplary evidence	Match
Use results of an earlier similar market consultation, or consult other public clients for results of earlier market consultations	No previous market consultations were performed on bridges or viaducts. Instead, another province was consulted on their experience with IFD construction.	*A meeting on NTA8085 – IFD fixed bridge construction took place on 14-4.*	N/A
Consult external parties in an early phase to put forward multiple perspectives	The market consultation took place with contractors and consultants who actively participated in research on circular bridges and/or developed circular bridge solutions. Other parties, such as component suppliers and demolition contractors were not consulted.	All parties had references that they participate in development programs or had in-house solutions on circular bridges. "Traditional contractors are not able to build a IFD bridge" (Project meeting, 28-3)	Yes
Perform the market consultation to collect innovative ideas from the market	Innovative ideas are checked, provided that innovations are on TRL 8 or 9.	Innovativeness is mentioned in the market consultation document, and explicitly limited to TRL 8 or 9 (Project documentation).	Yes
Check the feasibility and affordability of the circular plan in the market consultation	Feasibility and affordability of possible solutions were part of the written and oral questions asked to market parties.	"Ideally, the province does have a vision so the feasibility of solutions can be investigated for that vision" (Interview 6)	Yes
Validate the project ambition and specify the functional programme of requirements based on the market consultation	The market consultation is performed to gather information on state-of-the-art ideas on circular bridges. Based on that, ambitions were formulated and concretised into objectives.	"Validating the ambition can only is only possible if a market consultation is performed on a more detailed level" (Interview 3) "The market consultation is performed to detail the ambitions into objectives" (Interview 2)	No
Focus on the problem to be solved and not directly on the solution to the problem	Market parties were consulted on their vision on possible solutions and ways of collaboration. Diverging of solution took place, whereafter converging takes place, based on objectives are stated that are most suitable for the project, according to the project team.	One project member to the colleague: "Yes that is right, but remember that we are not talking about the solution, but about the variety of solutions" (Project meeting, 11-5).	Yes

5 Discussion

This study showed circular bridge development in the initiation phase from a client perspective by applying a pattern matching strategy. Pattern matching research describes and links theoretical and empirical patterns. Patterns are in this research core processes in the initiation phases of circular projects. The research aimed to formulate recommendations for the Province of Overijssel on the organisation of the initiation phase of circular bridge (re)construction by analysing the current process in practice and comparing that with state-of-the-art insights on circular development. Recommendations were validated in a panel discussion with project team members. For the research contribution, this section elaborates on the insights and implications that follow from the patterns. Then, the section discusses the research limitations and suggestions for future research. Appendix E presents a guideline that summarises practical recommendations towards the Province of Overijssel.

5.1 Contributions: Insights from pattern matching

The main contribution for science and practice is that this research provides new insights on how to integrate circularity in initiation phases by studying real-world bridge (re)construction. Building upon previous studies and guidelines on circular development in the construction industry, this research identified four patterns within the conceptual framework that are key for circular development in initiation phases. Subsequently, the study tested these patterns in practice for two bridge (re)construction projects using a pattern matching methodology, which resulted in insights for each pattern. The case of end-of-life bridges in the initiation phase of circular projects was not studied before. Also, most scholars overlooked the possibility to use a pattern matching methodology to obtain – new – insights on circular development in the initiation phase. In short, this research fills the gap on the limited knowledge and studies about the initiation phase of circular bridge development, which is relevant because of the many bridges that need treatment in the coming years and need to be circular to achieve sustainability goals. Next paragraphs discuss the main research contributions for the four patterns.

For the first pattern, which is formulating circular ambitions, previous studies showed the debate on defining circularity, implying that scholars and practitioners have different views on circularity (Geissdoerfer et al., 2017; Kirchher et al., 2017). This finding also yields within the context of this study where defining circularity and detailing circular ambitions was problematic. Practice showed that especially the lack of tactical level circular ambitions complicate formulating project ambitions. This is in

line with the suggestion on a shared circular vision and top-down support for circular project ambitions (Leising et al., 2018; Kooter, et al., 2021). Therefore, the development of a framework with circular ambitions on asset management level for asset categories is useful, which can be detailed on the project context using for instance an ambition web session, as suggested in literature (Schouten et al., 2022). However, it appears in practice that ambition sessions preferably do not take place every project due to the likelihood of similar outcomes for projects. This even increases the need for higher-level circular ambitions.

For the second pattern, which is about the project team composition, the research shows that circular project teams differ compared to linear projects in terms of required knowledge, competences and roles (Platform CB'23, 2021a). This study reinforces earlier findings of Schouten et al. (2022) that the complete core project team is present at stating ambitions. However, it also shows that circular commitment of team members significantly influences the formulation of ambitions. This is in accordance with earlier findings in literature, which states the importance of circular commitment in circular projects. (Versteeg Conlledo, 2019). Also, literature designates the importance of motivated project members in stating circular ambitions (Kooter, et al., 2021; Van Dijk, 2022). This research adds that particularly the predetermined scope – limited time and budget – and unclear project expectations negatively influences circular commitment, and thus motivation to develop circular bridges.

Also, previous studies stressed the lack of knowledge at clients (Adams et al., 2017; Hart et al., 2019; Gerding et al., 2021). Particularly, this research shows that specialistic knowledge – on for example circular bridge construction – was not in-house at the case projects, while it is desired in making well-considered choices. Because of that, tools such as life cycle analysis (LCA), environmental costs indicator (ECI), bridge circularity indicator (BCI), and ambition web are not always used despite that the project team recognised its relevance. For example, literature proposes to decide on suitable circular design strategies based on the project context and ambition (Platform CB'23, 2021a). However, practice showed that given the lack of knowledge on characteristics, advantages and disadvantages of strategies, no objective assessment could be made, while for instance the BCI framework could help to differentiate between the relative importance of reusability, adaptability, and design input for different bridge characteristics (Coenen et al., 2021).

The analysis also supports literature on the presence of multiple actors in an early phase, since these contribute to discussions on circular solutions from multiple perspectives (Nakajima & Russell, 2014; Platform CB'23, 2021a). However, this research downplays the claim to incorporate both the procurement advisor and circularity manager to the project team (Platform CB'23, 2021a). Platform CB'23 (2021a) suggests to incorporate a circularity manager, who is part of the management team. However, practice proposed that a circularity advisor with a niche of expertise is desired, who has an informative role and is consulted when needed. In that perspective, the research supports the finding that CE experts in the project team need to be involved in decision-making (Gerding et al., 2021).

For the third pattern, which is deciding to refuse, renovate or replace the bridge, the research expected that a circular performance, risk, and cost trade-off was made in asset management (AM) and project decision-making. AM requires explicit consideration of circularity, since it is key in deciding on assets and corresponding resource usage (Korse et al., 2016). However, the lack of understanding of circularity on AM level, and the AM system that is still in development impeded it. This is in line with Sanchez & Haas (2018), who state that practitioners lack methods to distinguish between building new and adaptive reuse. The results are also in line with the statement that tools such as LCA are needed in an early phase (Korse et al., 2016). The research adds the necessity to have an up-to-date AM system and that – internal – knowledge on LCA is present. This makes it possible to investigate the possibility of reusing components of other assets (Van Offenbeek-Kuipers et al., 2021). Next to that, clear agreements must be made to have a uniform organisational-wide approach on LCA assessment.

Besides the way the decision is made, the study demonstrates that the moment of decision-making and overlap between decisions heavily impacts the project continuation. To illustrate, formulating the circular ambitions was started, while at the same time the definitive decision on renovating or replacing the

bridge was not made yet. Literature suggests that circular projects require clear decision-making moments that integrate circular thinking using experts (Gerding et al., 2021). Rather, this project had no well-structured way of circular thinking and no CE experts, which resulted in a time consuming, difficult decision-making process. Based on literature, and the findings in practice, the research demonstrates that structure is needed. However, project members indicated in the panel discussion that there should always be room for iteration, as also introduced in literature (Kozminska, 2019).

For the fourth pattern, which is consulting the market, the research supports most of the literature. Market parties are consulted early in the process, innovative ideas are collected, and feasibility and affordability of the plan are checked, which is all in line with literature (Vos, et al., 2019; PIANOo, 2016). In the cases, especially the recruiting role of the project team was important, and therefore supports the idea on the need for new collaboration forms and intensive collaboration with market parties (Platform CB'23, 2021a; Venselaar et al., 2019; Leising et al., 2018). One of the methods is the market consultation, which is a suitable tool to gather information in an early stage, however practice showed that collaboration is not key in market consultations. Instead, one can speak about a one-way information exchange from the market to the client. There is no clear-cut answer on the usage of market consultations for circular development. In any case, market consultations are no prerequisite for circular bridge projects. Instead, it contributes to implement circularity (Vos, et al., 2019).

An interesting difference between literature and practice is that this study shows to perform a market consultation to collect information to state ambitions, while literature indicates to validate ambitions in the market consultation (Platform CB'23, 2021b; PIANOo, 2016). The reason given by project members is that this can only be done for market consultations at a higher level of detail. Therefore, the study supports the idea that having an ambition before the market consultation may exclude solutions, and if the ambition is changed, it may be hard due to the lack of support among project members to change the ambition (PIANOo, 2016).

5.2 Research limitations and future research

This research has limitations. First, this study has a limited scope, as it is restricted to the initiation phase. As a result, it cannot be investigated to what extent current practices would result in two circular bridges. Similarly, despite that research implications were validated during the study in a panel discussion, it still must be validated whether implications result in a circular bridge. Next to that, one should always be careful with generalising case study results, especially because of the qualitative nature of the study (Yin, 2003). During the study, the researcher was strongly dependent on information by the project team members. Therefore, testing findings on projects with another context is advised. Lastly, literature in this study is used to describe how the initiation phase of circular bridges should be organised based on state-of-the-art information on circular development. However, literature does not propose one single method to perform circular projects. Therefore, literature in this study is limited to circular economy in the construction industry, and selected based on its suitability for bridge construction by the researcher. For instance, market consultation can take place before and after the programme of requirements. Then, the researcher explained that it is suitable to do it before based on the case study context. Subsequently, this is compared with practice.

Several topics are addressed in this research that are interesting for further research. To start with, future research can investigate whether suggestions hold for other (re)construction projects of existing bridges, and whether findings also yield for other civil engineering structures, such as tunnels and sheet piles. This would allow to use the findings in a broader context. Also, future research can analyse the implications of circularity on the follow-up phases, of bridge construction from a public client's perspective, as this research was limited to the initiation phase. Future research could also focus on a decision-making tool that differentiates between multiple end-of-life options and circular indicators to select suitable circular design strategies. Besides that, an interesting topic would be to investigate how to establish collaboration between governmental bodies to achieve the benefits of potential bridge reuse and economies of scale. Lastly, research showed that employees see the benefits of circular- and value

thinking. However, this requires a change in the mindset of people, culture and functioning of the organisation. Therefore, future research can investigate how to embed value thinking at public clients.

6 Conclusion

This paper presents in-depth insights on the initiation phase of circular bridge (re)construction at the Province of Overijssel. The main research question of this paper was to investigate to what extent processes within the initiation phase of the bridges match with suggestions based on existing theories and literature on circular development and how can differences and similarities be explained, and existing processes be updated to integrate circularity?". Based on a case study, two real-world bridges are studied using a pattern matching methodology. The theoretical and empirical findings are organised into four processes that are particularly important for circular development: 1) formulating the project ambition, 2) composing the project team, 3) deciding to refuse, renovate or replace, and 4) consulting the market. By systematically comparing theory and practice for these processes, differences and similarities became clear where thereafter research contributions are made by showing insights for each process. In general, the four processes match in practice to different extents with theory. This illustrates the variety of insights on how to organise circularity in the initiation phase.

Regarding formulating the project ambitions, it is concluded that the lack of circular ambitions on asset management level and lack of knowledge on circularity among project members impede stating circular ambitions and objectives in projects. As a result, the research advises to state ambitions for asset categories, which can be detailed in projects with the project team based on its context and available resources.

Regarding composing the project team, the research indicated the importance of various roles in the project. Within the project team, procurement- and circularity advisors should have an informative role from the initiation phase to influence decision-making based on their expertise. However, it is project-dependent to what extent these roles are involved. For all team members, it is desired that circular knowledge becomes part of professional expertise. In the project team, commitment to the circular bridge project showed to be a key informal factor, and is in the study strongly influenced by an unclear project assignment, and predetermined project scope.

Regarding the decision to refuse, renovate or replace, it is concluded that the decision is preferably based on performance, expenditures, and risk assessment if the technical conditions allow that there are other measures than replacement. Circularity should be an integral part of the decision, which is preferably made during the asset management process to budget accurately. Also, pre-project planning may enhance the possibility for potential reuse of components.

Regarding consulting the market, the research concluded that market consultations are not a prerequisite for circular development and should be carefully used given its lack of monetary compensation and required effort from market parties. Nevertheless, the market consultation is a valuable method to obtain state-of-the-art information on circular developments from consultancies and contractors. As a result, the market is challenged to produce ideas, and the client can base and detail its project ambitions on the information from the market.

Building upon existing literature on circular development in construction, this paper contributes to a better understanding on how to integrate circularity in the initiation phase of projects of existing bridges that are – nearly – end-of-life. The insights provide further clarification for science on processes in the initiation phase of circular bridge (re)construction, and allow practitioners to use the insights and reshape their initiation phase for future bridge renovation and replacement projects. Further research is needed to assess the insights of this study in another context and to evaluate the effectiveness of insights for circular bridge development.

Declaration of interests

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendices

Table 5 – Abbreviation and meaning of sources of Evidence (Applicable for Appendix A-D)

Abbreviation	I_n	PM_{date}	CO_{date}	PD	FG_{date}
Meaning	Interview number (where n=1-10)	Project meeting (with date)	Conversation (with date)	Project documentation	Focus Group (with date)

Appendix A. Patterns compared: Formulating the project ambition

Theoretical pattern	**Empirical pattern**	**Evidence**	**Match**	**Barriers**	**Opportunities**	**Suggestion(s) for change**	**Potential for change**
Detail ambitions during the initiation phase of the circular project with the internal project team.	Ambitions are narrowed down in the initiation phase at the same time when it is decided to replace or strengthen the bridges. Ambitions are translated into objectives after the market consultation. Detailing ambitions was a complex process given the lack of vision from asset management and circular goals on tactical level.	A meeting to state objectives took place on 23-5 and 30-5. Thereafter, objectives were documented. "CE objectives is an organisational policy issue, we are ahead of that,…, the province needs a vision on circularity in infrastructure that helps us"($PM_{30\text{-}5}$)	Partly	No vision on circularity on asset management (tactical) level Inexperienced project team No consensus regarding circularity on project level	Tactical level CE ambitions as basis for operational level CE ambitions	State bridge ambitions for 80% on tactical level. The remaining 20% are ambitions on project-level given the uniqueness of bridges. These can be detailed during the initiation phase of the project.	High potential, but requires time to state asset management objectives.
Formulate client ambitions on sustainability and circularity performance with appropriate tools.	Circular and sustainable ambitions are stated on strategic level, with a sidenote towards the possibility for IFD construction. No tools are used by the project team or management.	"TCO should be minimised and improvement with respect to sustainability, circularity and climate adaptation" (PD). "Investigate whether NTA8085 – Industrial, flexible, and demountable (IFD) construction is applicable for this project" (PD)	No	Lack of appropriate tools and knowledge and competences to use tools. No circular vision on tactical level for bridge projects	Ambition web session tool	Ambition web session on project level and use that information for future projects. Organised by the internal circularity employee. OR Ambitions on asset categories (e.g. concrete fixed bridges) and specify ambitions on projects. (e.g. 80% tactical level and 20% operational level)	Medium potential for project specific ambition web session because of probability for similar ambitions for all projects. High potential for AM ambitions, *see first row.*
Incorporate circular design strategies to steer the design process	Despite that IFD needed to be researched according to the project brief, no circular strategies were specifically documented as ambitions to steer the process because there is no organisational vision regarding circularity.	"No strategies are used beforehand because both the organisation and project is in a pilot-phase" (I_4) "There is no strategy within the organisation, IFD is considered because of the working-group the province participated in" (I_8)	Partly	No organisational vision for the assets Lack of knowledge on circular design strategies Inexperienced project team members	Tactical goals on circularity in projects Project-specific goals that are complementary to tactical goals	Formulate a main circular objective, e.g. build conform IFD. Then use sub-criteria, such as low maintenance, which are subordinate to the main criterion. This can be studied in the initiation phase of the project	High potential, *see first row.* Circular objectives are preferred over circular design strategies.
State ambitions with multiple internal project members, as the client is responsible for stating the circular ambitions	Ambitions were formed with the core project team during the initiation phase. Ambitions are based on information from market parties.	A session to define objectives took place on 23-5 and 30-5 with the core project team using a presentation and discussion on what was learned by information from market parties.	Yes	Lack of tactical objectives results in difficulties on operational level. Inexperience Different commitment Lack of knowledge	N/A	N/A	N/A
Contribute with ambitions to strategic documents and organisational, (inter)national, and regional sustainability goals	Ambitions contribute to goals on strategic level, which are the national goals by the Ministry, the Regional Transition Agenda by the Province, and the AM plan of the organisation. Goals on tactical and operational level are not defined yet.	Project documentation states strategic goals by referring to 50% and 100% circular in 2030 and 2050, respectively.	Yes	The lack of concrete objectives on tactical level results in a big gap between strategic- and operational objectives	Formulation of CE goals on tactical level.	Define goals for infrastructure asset categories on AM level (bridges, viaducts). Example: strengthening is always preferred over replacement if the bridge is structurally safe, has same functionality, and has a lifespan of 30 years after strengthening.	High potential, *see first row.*

Appendix B. Patterns compared: Composing the project team

Theoretical pattern	Empirical pattern	Evidence	Match	Barriers	Opportunities	Suggestion(s) for change	Potential for change
Act as a promoter, financier, decision-maker and recruiter	The project team promotes because the need for a new bridge is clear, finances the project with available budget, makes decisions for project continuation, and recruits market parties to state ambitions.	*Observed by researcher during project meetings.*	Yes	N/A	N/A	N/A	N/A
Involve actors in an early stage using an integrated design strategy to improve CE performance	A large IPM team is set-up where multiple disciplines are present and put forward information based on their expertise	"This team is a relatively large IPM team given the nature (budget and scope) of the project" ($CO_{30\text{-}3}$) "Future project teams need to be lean" ($CO_{27\text{-}6}$)	Yes	Large team makes decision-making hard and time-consuming. Large project team is costly	Assess the potential contribution of project members and prevent double roles, such as contract manager and contract advisor.	Project team without redundant or double roles, this eases decision-making and is less costly.	High potential, consult advisors when needed, depending on project.
Incorporate a circularity and procurement manager in the project team	The project involved a procurement advisor and expert on innovative procurement. These people added knowledge on CE in the project, however no in-depth knowledge was present in relation to bridge construction. The employee on circularity was present in the project team, however not involved in the initiation phase.	"This project is different in the way that an expert innovative procurement and procurement advisor are present for creating an innovative environment and circular project result" ($CO_{3\text{-}4}$) "The internal employee on circularity was not involved because the project would go too fast into details" ($CO_{30\text{-}5}$)	Partly	No internal circularity expert, internal employee on circularity acts on organisational and policy-making level Costs Lack of in-depth knowledge on bridges	External expert via consultancy, however "external expert should not make a circular vision for us" However, problem on how to judge the consultant when you have no internal knowledge. Hire or educate internal expert.	Internal employee hosts ambition web session. External expert (consultant) needed, however should follow the vision of the province. Or: Internal expert with specialism such as ECI. Should follow the vision of the province	High potential, but consult internal employee if a session is done. However, session not mandatory. Experts preferably present internally. These can be part of the project team, but not the core team.
Add new competences, such as knowledge on new business-case conditions and circular economy in the team	Knowledge on innovative forms of procurement is present. These people also bring new competences. However, no in-depth knowledge is present on circularity in combination with existing expertise.	"Internal team members should be up-to-date with state-of-the-art circular developments, especially the project leader because he is in the lead, this is not the case now" (I_7) "Internal knowledge is largely available within departments of the province provided that knowledge is well-organised and facilitated" (I_6)	Partly	No specialised knowledge in-house Competences change, but people not Temporary contracts hamper continuous improvement Limited resources (time) of AM	Improve internal knowledge Facilitate and organize internal knowledge Hire knowledge Selection of people with right competences in the project Ensure time for asset management organisation to collaborate with project Ensure time for evaluations Up-to-date AM organisation	Outsourcing specialistic knowledge on for instance ECI. Organising internal knowledge and competences in Intranet.	High potential, but expert preferably present internally Medium potential that circular knowledge is part of professional knowledge, as this requires learning by employees.
Select internal team members based on their influence, interest and competences needed in a circular project	A procurement advisor and expert innovative procurement were incorporated because of the need for circularity in the project. There was no specific method for composing the project team.	"Experience with circularity is not used to find the right team members, also because there is marginal experience within the province" (I_1) "The procurement advisor and expert innovative procurement are present because of the necessity of circularity in the project" ($CO_{25\text{-}5}$)	Partly	Lack of experience within organisation Lack of expertise in relation to circularity within organisation	Facilitate and organise knowledge of employees internally because knowledge may be present, but may be unknown among employees	Select project leader for initiation and initiation phase which has circular knowledge, can think creative and is decisive.	High potential, but not necessarily project leader. All project leaders and employees need to think creative, have circular knowledge as part of their expertise and be decisive.
Create a uniform vision, circular commitment, and philosophy within the project team	There was substantial difference in vision and commitment towards circular solutions and collaboration forms. After the market consultation commitment increased and converged between team members. However, a uniform vision was lacking given the lack of a vision and circular goals on tactical level.	"What goes well is the increasing involvement and the will, project members to apply circularity in the project" (I_3) "The openness for circular solutions grew during the project due to the information from the market, while initially the purpose market consultation was not well-understood" (I_6)	No	No tactical CE ambitions as basis for project vision Lack of experience and knowledge on circularity. Competences of team members Predetermined project scope	Make sure that project brief is well-understood by everyone by mentioning tactical objectives Organise ambition session to indicate the importance of circularity in relation to other project aspects.	Make a distinction between a project brief for the initiation phase, and project brief for the realisation phase. Develop organisational circularity ambitions	High potential. A clear project brief for the initiation phase is required. Also, the leading role of the project leader is important in creating commitment. However, despite a uniform vision ambitions can still change in the iterative process.

Appendix C. Patterns compared: Deciding to refuse, renovate of replace

Theoretical pattern	Empirical pattern	Evidence	Match	Barriers	Opportunities	Suggestion(s) for change	Potential for change
Incorporate performance, risk, and costs into AM and project decision-making, and translate it into functional performance, sustainability and circularity performance, risk, life cycle costs and environmental costs	The AM decision was based on the high risk with regard to structural safety in the coming years. As a result it was questionable whether the performance of the bridge would suffice in the next years. Costs did not play a major role. However, costs play a major role in deciding to renovate or replace. No sustainability and circularity factors were incorporated in the decision-making *The usage of PRK in the project was not within the scope of this research.*	"CROW-CUR recommendation has the goal to meet the information provision with respect to structural safety of bridges owned by decentral governmental bodies, ..., Based on the CROW-CUR most risky objects are tested, …, 'as a result the bridges need to be renovated or replaced" (PD) "When the costs to strengthen the bridge outweigh the costs for replacing it, then the bridge will be replaced" ($PM_{8\text{-}3}$) "Bridge I is replaced because of the risk, as it is uncertain what the structural condition of the bridge is" ($CO_{11\text{-}4}$) "Bridge II is strengthened because the structural performance has shown to be sufficient for the current traffic load, provided that the concrete check is sufficient too" ($CO_{11\text{-}4}$)	No	No organisational vision on circular indicators performance No expertise to use LCA tool in early phase	State circular ambitions on AM level Use LCC Hire expert for LCA and ECI calculations	Consider circularity as integral part of performance, where circularity can have multiple indicators, depending on organisational vision. Examples are material usage, waste, and energy. A lifecycle approach should be performed, including expected lifespan. Use LCC and environmental costs as part of costing. Define risk for specific options.	High potential to be implemented in the coming years, AM planning is in development. However, expertise needed on LCA-tools in AM decision-making
Investigate whether there are potential materials or components within the portfolio of assets that can be used in the bridge project	Investigated, but no components were available within assets of the province. Assets of other public clients could be utilised, provided that this is available within the timeframe of the project. Components of case bridges could not be reused on the same functionality due to the material performance.	"The province does not have a depot with components for reuse, this has to be hired or outsourced to contractor ($PM_{8\text{-}3}$)" "We should know in advance when bridges (of other public clients) become available, this is not the case in this project" ($CO_{15\text{-}6}$)	Yes	Regulations on structural performance of components Availability of components within planning Portfolio of province is viewed as too small	Programmatic long term planning Consider wider portfolio of bridges of for instance RWS or other decentral governments	Long term planning of bridge renovation projects with reused components to check availability of components	High potential, AM-plan in development, including complete decomposition of assets
Choose circular design strategy based on the circular ambition and project context	The relation for suitable circular indicators and circular design strategies for the project context were not well-understood by the project team because of the lack of experience with circular projects. *A definitive decision on strategies has not been chosen at the moment of research.*	"The choice for circular design strategies has to be made based on LCC and environmental costs, however there is less attention within the organisation to these factors" (I_7) "At the moment there is no substantiated method to make the choice, also because there is no organisational vision, the project team does what they think is the best option,…, performance, risk and costs, are suitable to make decision on solution types and to use that decision for future projects"(I_2)	No	Team not familiar with circular design strategies to objectively assess most suitable option for the project	Use BCI in relation to relative importance of project context factors Use performance risk and costs to assess alternatives	Performance, Risk, and Costs to decide on suitable solutions for the project, and use this substantiated decision for future projects. Also, use for instance relations between bridge characteristics and reusability, adaptability, and design input of BCI to state circular strategy for projects.	High potential, but requires additional research on what constitutes choices for circular design strategies

Appendix D. Patterns compared: Consulting the market

Theoretical pattern	Empirical pattern	Evidence	Match	Barriers	Opportunities	Suggestion(s) for change	Potential for change
Use results of an earlier similar market consultation, or consult other public clients for results of earlier market consultations	No previous market consultations were performed on bridges or viaducts. Instead, another province was consulted on their experience with IFD construction.	A meeting on NTA8085 – IFD fixed bridge construction took place on 14-4.	N/A	No earlier market consultation available	Save lessons-learned from this project and use in future similar projects. Contact market parties using other mechanisms than market consultation	Perform market consultations for categories of assets once in *x* year. Document information, and refresh information once a year. Collaborate with market parties by other ways, such as informal conversations, competitive dialogue, design team agreement, etc.	High potential, but documenting information required to be put into action by for instance a dedicated internal employee.
Consult external parties in an early phase to put forward multiple perspectives	The market consultation took place with contractors and consultants who actively participated in research on circular bridges and/or developed circular bridge solutions. Other parties, such as component suppliers and demolition contractors were not consulted.	"Traditional contractors are not able to build a IFD bridge" ($PM_{28\text{-}3}$) All parties had references that they participate in development programs or had in-house solutions on circular bridges.	Yes	Limited time of market parties Time consuming to consult besides contractors and consultants also suppliers and demolition contractors	Consult demolition contractor in an early phase to investigate the possibility to dismount the object. Involve suppliers for their knowledge on material and component production.	Presence of demolition contractor in early phase (e.g. in market consultation), since projects should not start by thinking in new materials.	Medium potential. Can be involved, but not specifically needed because demolition contractor is often contracted by main contractor who is involved. Instead, involve demolition contractor in design team agreement
Perform the market consultation to collect innovative ideas from the market	Innovative ideas are checked, provided that innovations are on TRL 8 or 9.	Innovativeness is mentioned in the market consultation document, and explicitly limited to TRL 8 or 9 (PD).	Yes	Risk aversion	Risk sharing Innovation project, optimize solution and use innovation for future assets	Ask for a TRL7 solution, learn from project and let market party optimize. Then use solution in next projects. Risk sharing using for instance a design team agreement. Client can bear the risks with a low chance of occurrence, else it is hard to achieve innovation.	Low potential. Team agrees that bearing more risks is needed when striving at innovation, such as circular constructions. However, it is an organisational-wide topic, where the project team does not have major influence on.
Check the feasibility and affordability of the circular plan in the market consultation	Feasibility and affordability of possible solutions were part of the written and oral questions asked to market parties.	"Ideally, the province does have a vision so the feasibility of solutions can be investigated for that vision" (I_6)	Yes	No organisational objectives	Gain knowledge from the market to shape organisational vision and learn for the future Specific market consultation in the future	For this knowledge level within the organisation, a market consultation to gain information on state-of-the-art circular bridge development is desired. In the future, with higher knowledge level and organisational vision, it is appropriate to start more specific market consultations.	N/A
Validate the project ambition and specify the functional programme of requirements based on the market consultation	The market consultation is performed to gather information on state-of-the-art ideas on circular bridges. Based on that, ambitions were formulated and concretised into objectives.	"Validating the ambition is only possible if a market consultation is performed on a more detailed level" (I_3) "The market consultation is performed to detail the ambitions into objectives" (I_2)	No	Having an ambition before the market consultation may exclude solutions.	Specific market consultation with higher level of detail in the future	No suggestions for change. At this knowledge and ambition level, a more general market consultation is desired, however not required. Also future consultations should formulate ambitions based on latest developments that follow from the consultation	N/A
Focus on the problem to be solved and not directly on the solution to the problem	Market parties were consulted on their vision on possible solutions and ways of collaboration. Diverging of solution took place, whereafter converging takes place, based on objectives are stated that are most suitable for the project, according to the project team.	"Yes, that is right, but remember that we are not talking about the solution, but about the variety of solutions" ($PM_{11\text{-}5}$).	Yes	Vendor lock-in due to solutions of market parties	N/A	Stay objective, and prevent to dive into one solution of one specific market party.	N/A

Appendix E. Guideline Province of Overijssel – practical recommendations

See next page

Guideline: Circulariteit in de verkenningsfase van nieuwbouw en rehabilitatie brug projecten van de Provincie Overijssel

Klik op onderstreepte tekst voor doorverwijzing naar het desbetreffende onderwerp

Asset Management

Project – Nieuwbouw & Rehabilitatie

Programma management

Initiatie → Verkenning → Planvorming → Voorbereiding → Uitvoering → Nazorg

Fasen Projectmatig werken

4 aspecten die van belang zijn voor circulaire brug ontwikkeling

De beheerkeuze

Asset Management (AM) heeft de mogelijkheid om *R0 – Refuse* uit de R-Ladder toe te passen, in dit geval wordt er geen project gestart. De beheerkeuze voor het kunstwerk heeft grote invloed op de wijze van circulair ontwerpen en de circulaire prestatie. Zo kan AM kiezen om niets te doen, groot onderhoud te plegen, te versterken, of te vervangen. Daarnaast is het moment en de mate van invulling van de beheersmaatregel van grote invloed op het project.

Suggestie voor geschikt moment:

- *Tijdens AM*
- *Tijdens AM (deels) en verkenning*

Het projectteam

Projecten die circulariteit beschouwen vergen – vergeleken met lineaire projecten – nieuwe kennis en competenties binnen het interne projectteam van de opdrachtgever. Daarnaast zijn informele projectvariabelen zoals uniforme visie en inzet van belang.

Suggestie voor geschikt moment:

- *Opstellen projectteam na initiatiefase door projectleider in het projectplan*

Circulaire ambities en uitgangspunten

Circulaire ambities zijn de basis voor een gewenste circulaire projectuitkomst. Circulaire ambities vormen samen met overige ambities de integrale projectaanpak. In de gewenste situatie worden AM-ambities vertaald naar projectambities. Gedurende dit proces dienen ambities omgezet te worden in – meer concrete – uitgangspunten, aangezien gedetailleerde uitgangspunten de succes voor circulariteit vergroten.

Suggestie voor geschikt moment:

- *AM-ambities en uitgangspunten detailleren tijdens verkenning*

Marktconsultatie

Een marktconsultatie is een georganiseerde bijeenkomst voor een aanbesteding tussen een (of meerdere) marktpartij(en) en publieke opdrachtgever met als doel het vergaren van informatie vanuit de markt. Het wordt vaak gebruikt in het geval dat de opdrachtgever over onvoldoende informatie beschikt om een ambitie op te stellen en/of opzoek is naar innovatieve oplossingen.

Suggestie voor geschikt moment:

- *Tijdens verkenning*
- *Of tijdens AM indien verkenning richting AM proces gaat*

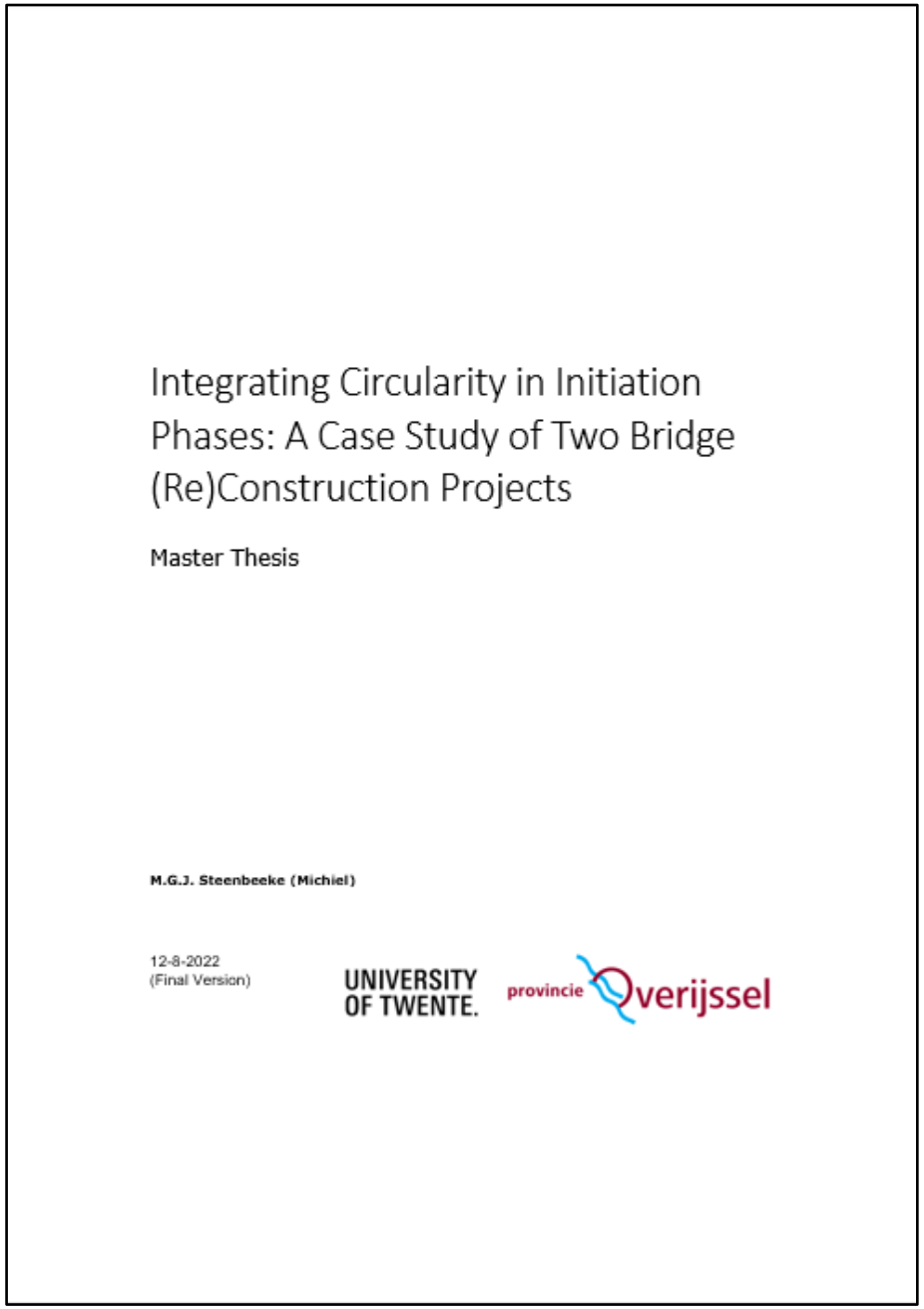
Achtergrondinformatie Onderzoek

Guideline is onderdeel van de Master Thesis van M.G.J. Steenbeeke (Michiel)

Volgende

Achtergrondinformatie

- Deze guideline is opgesteld als onderdeel van de Master Thesis van Michiel Steenbeeke, Master student Construction Management and Engineering aan de Universiteit Twente.
- Het onderzoek is uitgevoerd in opdracht van Provincie Overijssel, Eenheid Wegen en Kanalen, Team Project Sturing tijdens de periode Maart – Augustus 2022.
- Deze guideline bevat adviezen uit het onderzoek die potentieel gebruikt kunnen worden in toekomstige circulaire vervangings- en/of versterkingsopgaven van bruggen.
- Het onderzoek is gebaseerd op twee betonnen bruggen die vanwege constructieve veiligheid vervangen of versterkt dienen te worden.
- Voor het gehele onderzoek verwijs ik graag naar de scriptie “Integrating Circularity in Initiation Phases: A Case Study of Two Bridge (Re)Construction Projects”.


Integrating Circularity in Initiation Phases: A Case Study of Two Bridge (Re)Construction Projects

Master Thesis

M.G.J. Steenbeeke (Michiel)

12-8-2022
(Final Version)

UNIVERSITY OF TWENTE.

provincie overijssel

De beheerkeuze

- Projecten die vallen onder het proces Nieuwbouw en Rehabilitatie zijn investeringsprojecten. Deze projecten voegen waarde toe.
- Het hoofddoel van asset management is de instandhouding van kunstwerken binnen het provinciale areaal. Het beheerproces heeft grote invloed op de circulaire prestatie door:
  - Er voor te kiezen niets te doen (R0 – Refuse)
  - Groot onderhoud te plegen (Intern Proces Groot Onderhoud)
  - Te versterken (Intern Proces Nieuwbouw & Rehabilitatie)
  - Te vervangen (Intern Proces Nieuwbouw & Rehabilitatie)
- Een investeringsbeheerkeuze wordt gemaakt indien:
  - De technische staat van een kunstwerk onvoldoende is
  - Wanneer versterken of vervangen de voorkeur heeft boven klein of groot onderhoud op basis van levenscyclusbenadering
  - Een brug integraal wordt aangepakt als onderdeel van bijvoorbeeld wegonderhoud
- De beheerkeuze vindt bij voorkeur plaats binnen Asset Management, maar kan ook tijdens de projectverkenning plaatsvinden.
- Het advies is om de beheerkeuze te maken op basis van een Prestatie-Risico-Kosten (PRK) afweging, waar circulariteit een integraal onderdeel van is.
- Door het beschouwen van circulariteit zijn asset management, projecten, en programma management nauw met elkaar verbonden. Bijvoorbeeld: specifieke circulaire ambities en ontwerpstrategieën beïnvloeden het beheer van kunstwerken, en het programmeren van budget voor deze kunstwerken.

Geschikt moment voor de beheerkeuze

Tijdens Asset Management

Omschrijving

- De asset manager stelt vast dat functionele prestatie onvoldoende is. Vervolgens wordt a.d.h.v. een PRK afweging een beheerkeuze gemaakt. Tijdens deze stap wordt de verkenningsfase van het project bij asset management aangesloten, zodat de keuze niet in het project wordt. De verkenning vindt bij voorkeur voor de budgetaanvraag plaats. Hierdoor is het vanaf de start van het project duidelijk wat de definitieve beheerkeuze is.

Voorwaarden

- Beschikbare middelen:
  - Personeelscapaciteit
  - Tijd
  - Informatie: Constructieve gegevens over het object vanuit het archief & aanvullend onderzoek

Voor- en nadelen

+ Gericht budgetteren voor lange termijn in *meerjarenuitvoeringsplan* en daarom nauwkeurigere budget aanvraag vanuit programma management. De verkenning vindt dus plaats voor de budgetaanvraag

+ De technische staat van kunstwerken, en beheerkeuze is duidelijk voor het project. Bijkomend voordeel is dat dit inzicht in de *meerjarenopgave* de mogelijkheid geeft om via een portfolio aanpak aan te besteden zodat er een *economy of scale* behaald wordt. Daarnaast maakt het mogelijk om componenten uit te wisselen en/of te hergebruiken door vroegtijdig te plannen.

- Benodigde middelen binnen de AM-organisatie die momenteel wellicht niet beschikbaar zijn. Bijvoorbeeld: LCA expertise en beschikbare tijd.

Tijdens Verkenningsfase in project

Omschrijving

- Asset manager doet voorstel tot vervangen of versterken van het kunstwerk. De keuze is gemaakt a.d.h.v. een inschatting (via inspectierapport) op constructieve veiligheid en bijbehorend risico, of de brug is onderdeel van een wegvervangings-project en wordt integraal meegenomen in het project. Daarna wordt tijdens de verkenningsfase onderzoek gedaan naar de definitieve beheerkeuze.

Voorwaarden

- Door de keuze in de verkenningsfase te maken, zijn aanvullende kennis en competenties in het projectteam nodig om het onderzoek uit te kunnen voeren.
- Projectscope in projectopdracht – tijd en geld – houdt rekening met ruimere verkenningsfase om passende keuze te maken a.d.h.v. beschikbare constructieve gegevens.

Voor- en nadelen

+ Onderzoek naar circulaire oplossing die het beste is voor de project specifieke context, zoals locatie.

- Indien de definitieve beheerkeuze in het project afwijkt van de voorlopige beheerkeuze door de asset manager (bijvoorbeeld: de brug wordt vervangen i.p.v. versterkt), dan kan er budgetspanning ontstaan. Programmamanagement heeft namelijk een budgetaanvraag gedaan waarin van afgeweken wordt.

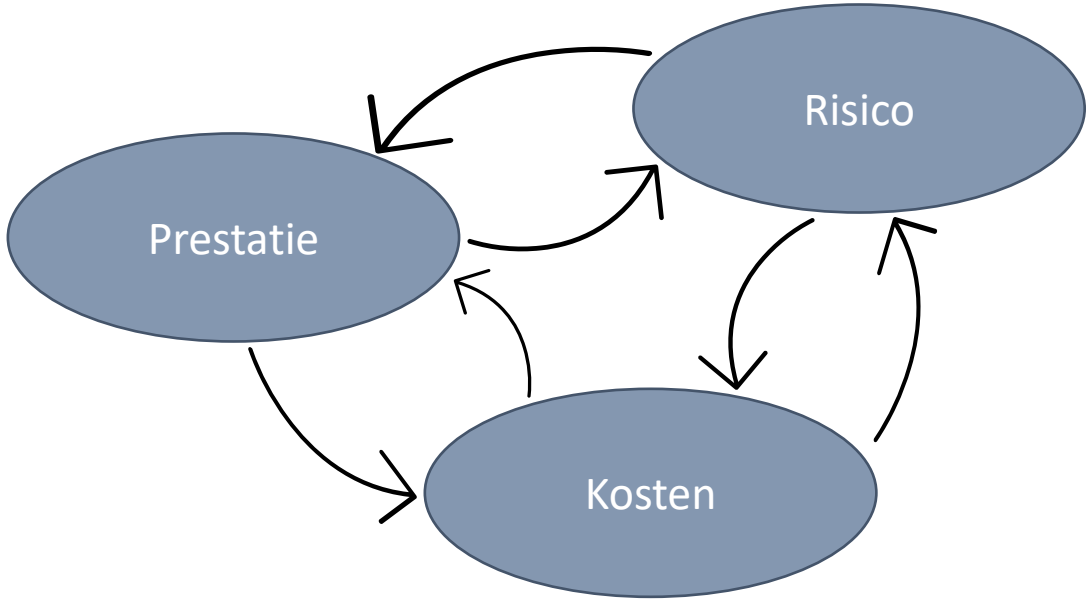
- Verkenning tot mogelijkheden betreft de definitieve beheerkeuze vergt middelen die mogelijk niet beschikbaar zijn (tijd, geld, personeel).

- Onduidelijke scope (door niet-definitieve beheerkeuze) brengt onzekerheden en risico's met zich mee

Op basis van de onderzoeksresultaten is het wenselijk dat de keuze binnen AM gemaakt wordt. De AM organisatie is tijdens het onderzoek gestart met het opstellen van het Meerjarenopgave 2028-2031 waarin de beheerkeuze via de PRK-afweging moet plaatsvinden voor het programmeren en projectstart.

Het afwegen van de beheerkeuze

- Tot op heden werd de beheerkeuze gebaseerd op constructieve veiligheid en bijbehorend risico, waarna het kunstwerk vervangen werd. Om te kijken of versterken een optie is, is het gebruik van PRK gewenst voor duurzame keuzes tijdens AM (en het project).
- **Voorwaarde**: Voor investeringsprojecten is PRK is alleen mogelijk als de technische staat van het kunstwerk een versterking toelaat voor de gewenste levensduur.
- De PRK afweging beschouwd circulariteit als integraal onderdeel van factoren:
- **Prestatie** van het kunstwerk gaat naast de functionele prestatie ook over de circulariteitsprestatie, en overige prestatiecriteria. Kortom:
  - Functionele prestatie
  - Circulariteitsprestatie
  - Overige prestatie criteria
- **Risico** is de kans dat het object niet meer voldoet, of gaat voldoen. Het wordt bepaald a.d.h.v. *kans x gevolg.*
- **Kosten** zijn naast investeringskosten (CAPEX), ook operationele kosten (OPEX), deze vormen samen de levenscycluskosten. Daarnaast is het noodzakelijk om milieukosten te berekenen om een duurzame afweging te maken. Kortom:
  - Levenscyclus kosten
  - Milieu kosten



Prestatie

- Functioneel
  - Voldoen aan technische staat (bijv. normen zoals de Eurocode/NEN)
  - Voldoen aan gewenste functionaliteit
  - In geval van levensduurverlenging is er voor (betonnen) bruggen aanvullend onderzoek nodig
- Circulariteit
  - Materiaalgebruik
  - Afval productie (of reductie)
  - Energieverbruik (relevant voor beweegbare kunstwerken)
  - Losmaakbaarheid
  - Niet-gemixt materiaal
  - Hernieuwbare grondstoffen
  - Hergebruikt materiaal of componenten
- Overige prestatie criteria, zoals:
  - Bijv. natuurinclusiviteit
  - NOx en CO2 emissies

Risico

- Risico's in zowel de aanlegfase als beheerfase
- Risico's a.d.h.v. organisatorische waarden. Bijvoorbeeld:
  - Doorstroming
  - Veiligheid
    - Sociale veiligheid
    - Verkeersveiligheid
  - Leefbaarheid (omgeving)
  - Kosten
  - Imago
  - Milieu

Kosten

- Kosten = investeringskosten + operationele kosten + milieukosten
- Levenscycluskosten (LCC)
  - Investeringskosten
  - Operationele kosten
    - Kosten van klein en groot onderhoud
    - Kosten van versterking
- Milieu kosten
  - Milieu Kosten Indicator (MKI)
- Bepaal een scope voor alle kunstwerken zodat LCC en MKI consistent benaderd worden
  - Bijv. een levenscyclusbenadering van 100 jaar, of maximale levensduur van een alternatief
  - Bijv. LCC en MKI altijd inclusief transportafstand

Implicaties:

- Het inbedden van circulariteit in de PRK-afweging betekent dat een LCA tool nodig is tijdens de AM fase.
- Het is echter ook mogelijk om de afweging te maken a.d.h.v. *expert judgement* en een score toe te voegen via bijvoorbeeld een ++ tot -- schaal.
  - Voordeel: geen kwantitatieve LCA expertise (via bijvoorbeeld DuboCalc) nodig om tot circulaire inschatting te komen
  - Nadeel: minder nauwkeurige en geen gelijkwaardige inschatting (geen eenduidige eenheid, bijvoorbeeld Euro's). Indien minimale verschillen LCA toch nodig.
- De keuze voor circulariteitsindicatoren is een beleidskeuze. Het advies is daarom om circulariteitsambities voor het areaal op te stellen op basis van de circulaire principes. Deze dienen geborgd te worden in het AM plan. Daarnaast is er de project specifieke context die de keuze voor indicatoren bepaald.

Versterken & Vervangen

- Het versterken van de brug is een optie die behoort tot levensduurverlenging
- Eerder werd geadviseerd om de PRK afweging tijdens de AM fase te maken. Daarom is aanvullend onderzoek nodig in AM fase betreft de constructieve veiligheid:
  - Als volgende stappen voldoen, dan is het mogelijk om een brug te versterken voor een gewenste levensduur.
    - ✓ Stap 1: Visuele inspectie
    - ✓ Stap 2: Constructieve scan
    - ✓ Stap 3: Constructieve herberekening & restlevensduurbepaling
    - ✓ Stap 4: Aanvullend betononderzoek
- Het advies is om de gewenste levensduurverlenging te baseren op het verwachte gebruik tijdens de levensduur

Ontwerpstrategieën

(Platform CB'23, 2021)

- Ontwerpen voor preventie
- Ontwerpen voor reductie van levenscyclusimpact
- Ontwerpen voor toekomstbestendigheid
- Ontwerpen met hergebruikte materialen
- Ontwerpen met secundaire materialen
- Ontwerpen met hernieuwbare grondstoffen

- De bouwopgave (ambitie en context) bepaald welke ontwerpstrategieën van toepassing zijn.
  - Waardevolle tool is de Bridge Circularity indicator (BCI). De BCI linkt projectfactoren (type overspanning, mate van omgevingsdynamiek, en ontwerplevensduur) aan circulariteitsindicatoren (hergebruik/aanpasbaarheid, materiaal input). (Coenen et al, 2021)
- Advies voor portfolio aanpak binnen provincie om schaalgrootte te creëren en opdrachtnemers de kans te geven om innovaties uit te proberen en door te ontwikkelen.
- Portfolio aanpak en pre-project planning via het meerjarenplan maakt bruggen en onderdelen inzichtelijk voor potentieel hergebruik
  - **Aandachtspunt**: Provincie heeft geen depot voor opslag.

Het projectteam

- Circulaire projecten vergen nieuwe kennis en competenties. Deze kunnen volgen vanuit nieuwe en bestaande projectteamleden. Tegelijkertijd is het gewenst dat het projectteam Lean is i.v.m. kosten en arbeidskrapte.
- Daarom is het advies om contractmanagers, inkoopadviseurs en circulariteitsexperts te betrekken via een informatieve rol.
- Zij zijn bij voorkeur aangesloten vanaf de verkenningsfase aangezien bepalende keuzes worden gemaakt die de projectvoortgang beïnvloeden, bijvoorbeeld, bijvoorbeeld contracttype of circulaire ambitie. Op deze manier worden zij geraadpleegd wanneer nodig en kunnen zij invloed uitoefenen op keuzes, maar blijft de keuze wel bij de projectleider en managementteam.
- De opgave bepaalt echter in hoeverre deze personen aansluiten.
- Projectteam grootte heeft voor- en nadelen:
  - Voordeel: verschillende perspectieven op circulaire oplossingen
  - Nadeel: maakt het maken van keuzes moeilijker. Kosten.

Voorbeeld projectteam - Kernteam verkenningsfase

- Projectleider
- Projectondersteuner
- Toezichthouder
- Technisch Manager en/of Constructeur

Voorbeeld projectteam – via informatieve rol

- Omgevingsmanager
- Inkoopadviseur
- Contractadviseur en manager
- Beleidsmedewerker duurzaamheid en circulariteit
- Circulariteit adviseur met niche expertise:
  - MKI berekeningen
    - Momenteel niet intern aanwezig, inhuur noodzakelijk

Kennis en competenties

Uit het onderzoek blijkt dat zowel nieuwe kennis als competenties wenselijk zijn in de verkenningsfase van projecten die werken met circulariteit.

Kennis

- Projectteamleden in circulaire projecten hebben bij voorkeur kennis van circulariteit in combinatie met vakinhoudelijke kennis.
  - Voorbeeld: *Het begrijpen hoe circulaire keuzes het project beïnvloed over de gehele levenscyclus*
- Op lange termijn is het wenselijk dat circulaire kennis vanzelfsprekend onderdeel is van de vakinhoudelijke kennis.
- Veel benodigde kennis voor de verkenningsfase is beschikbaar binnen de provincie (zoals innovatief inkopen), deze kennis moet wel bekend zijn binnen verschillende afdelingen. Daarom is het organiseren van kennis (tussen afdelingen) wenselijk.
- MKI en LCA kennis is noodzakelijk voor het beoordelen van de beheerkeuze en bijv. materiaal alternatieven.

Competenties

- Uit het onderzoek blijkt dat benodigde competenties niet wezenlijk verschillend zijn met lineaire projecten.
- Er een aantal competenties benoemd die volgens het projectteam van belang zijn in een circulaire verkenningsfase:
  - Creativiteit en het kunnen divergeren
  - Kritisch denken
  - Besluitvaardigheid en het kunnen convergeren

Project overstijgende aanbeveling:
Tijdelijke contracten van personeel verminderd mogelijkheid tot *continious improvement* (Plan-Do-Check-Act). Dit maakt het borgen van kennis uit bijvoorbeeld voorgaande circulaire brug projecten nog belangrijker.

Uniforme circulaire visie en inzet *(Commitment)*

- De circulaire visie en mate van circulaire inzet van projectteamleden zijn informele projectvariabelen die grote invloed uitoefenen op het project.
- Het begrip Circulariteit heeft nog geen geaccepteerde definitie, daarom is het advies om vanaf de project startup (of via het ambitieweb) de kansen voor circulariteit te beschouwen en te definiëren wat circulariteit betekent voor het project.
- Uit het onderzoek blijkt dat de mate van circulaire inzet wordt beïnvloed door:
  - Circulaire vraag in projectopdracht in combinatie met onbekendheid van oplossingen
  - Voorgeschreven projectscope: beschikbaar budget en tijd (opleverdatum)
- In de ideale situatie dienen de circulaire ambities op asset management als basis voor het formuleren van de projectambitie.

Ambities en uitgangpunten

Momenteel zijn er binnen de provincie geen circulaire ambities geformuleerd op tactisch niveau.
Het vertalen van strategische ambities naar projectambities, in combinatie met het huidige kennisniveau, zorgt voor moeilijkheden in de verkenningsfase.
Daarom zijn er een tweetal adviezen:

- **Advies 1:** Formuleer uitgangspunten betreft circulariteit op asset niveau, bijvoorbeeld per asset categorie (bijv. vaste bruggen, wegen, etc.)
- **Advies 2:** Asset niveau uitgangspunten dienen als basis voor projectambities. Er is dus ruimte voor de project specifieke context.

Invulling:
Via bijvoorbeeld de 80-20 regel: Circulaire uitgangspunten voor 80% op tactisch niveau, scherp deze aan voor de overige 20% op operationeel niveau (mogelijk d.m.v. marktbenadering via bijv. marktconsultatie)

Tactisch niveau – Asset Management

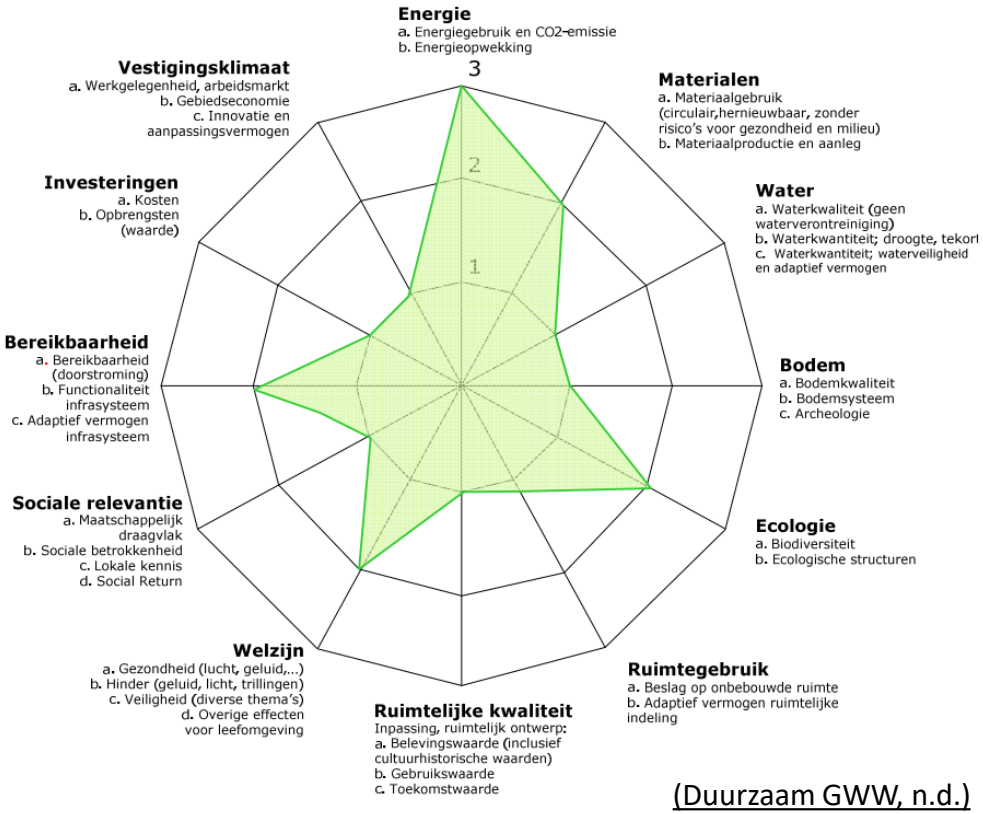
- Het opstellen van circulaire ambities en uitgangspunten in het AM-plan voor asset categorieën.
- Voorbeelden:
  - Het streven naar standaardisatie conform Nederlandse open standaard
  - Het minimaliseren van materiaalgebruik met xx ton per strekkende meter t.o.v. standaard ontwerp
  - Het streven naar losmaakbaarheid
  - Het streven naar oplossingen met hernieuwbare materialen

Operationeel niveau - Projecten

- Tijdens de Project Startup is het wenselijk om gezamenlijk ambities te bespreken. Dit kan via een ambitieweb sessie. Hierin worden naast circulaire thema's ook andere thema's besproken zodat het project integraal benaderd wordt. Het bespreken van ambities creëert voor projectteamleden duidelijkheid wat de circulaire visie is in het project.
- Hier vindt overleg plaats naar in hoeverre AM niveau ambities passend zijn. Vervolgens kunnen ambities aangescherpt of afgezwakt worden op basis van de project context.
- Het bespreken van circulaire ambities is belangrijk om een meer uniforme visie en inzet te verkrijgen voor de circulaire opgave.
- Een logische stap na de ambities is het opstellen van uitgangspunten.

Ambitieweb sessie

- Binnen de eenheid Wegen & Kanalen is het ambitieweb ingevuld op strategisch niveau
- Het advies is om deze strategische doelen te vertalen naar tactische doelen (asset management niveau) voor asset categorieën
  - Vaste bruggen / wegen / etc.
- Vervolgens ambities aanpassen op basis van de project context
- Het advies is dat het gehele projectteam bij deze sessie aanwezig is, om een uniforme (circulaire) visie en inzet te bewerkstelligen
- De sessie met het interne team wordt georganiseerd door de interne beleidsmedewerker duurzaamheid en/of circulariteit
- Uitgangspunten vormen de basis voor circulaire ontwerpstrategieën
- Het niveau van circulaire uitgangspunten zijn verbonden aan risico's.



(Duurzaam GWW, n.d.)

Marktconsultatie en Circulair Inkopen

- De marktconsultatie is een methode om informatie te vergaren bij opdrachtnemers. Deze informatie is niet bekend binnen de publieke opdrachtgever. Daarnaast resulteert het benaderen van de markt in innovatieve ideeën die helpen invulling te geven aan passende oplossingen en samenwerkingsvormen voor de opgave.
- Marktconsultaties hebben voor- en nadelen, daarnaast zijn er alternatieven
- Er is geen eenduidige manier die bepaalt wel of geen marktconsultatie te houden
- Indien gekozen wordt voor een marktconsultatie, dan is het advies om dit per asset categorie te doen (bijv. vaste bruggen / beweegbare bruggen / wegen / damwanden / etc.). Op deze manier wordt de druk op marktpartijen verkleind.
  - **Voorwaarde**: informatie vanuit marktconsultaties wordt geborgd binnen de organisatie.
- Overweeg om sloopaannemer te betrekken in de marktconsultatie voor informatie rondom nieuwste demonteer technieken wanneer hergebruik prioriteit heeft.

Marktconsultaties

Voordelen

+ Veel informatie uit de markt

+ helpt ambities, doelen, en aanbestedingscriteria voor het project aan te scherpen

+ innovatieve ideeën in projecten implementeren die niet eerder bekend waren binnen de provincie

+ Geen vergoeding (voordeel voor publieke opdrachtgevers)

Nadelen

- Niet zozeer samenwerking en informatie-uitwisseling met partijen
- Geen vergoeding (nadeel voor marktpartijen)
- Nakijken consultaties kost veel tijd voor opdrachtgever, inclusief het verplicht opstellen van een geanonimiseerd rapport.
- Marktconsultatie kost tijd voor marktpartijen (en provincie). Problematisch in tijd van arbeidsschaarste.
- Marktpartijen geven veel informatie, maar ook er zijn nog altijd veel onduidelijkheden omdat zij niet alle informatie delen. Bijvoorbeeld: unieke oplossingen van de organisatie.

Alternatieve samenwerkingsvormen & risico's

- Ga in **gesprek** met marktpartijen door ze bijvoorbeeld op te bellen, of bijeenkomsten te bezoeken.
- **Concurrentiegerichte dialoog** om daadwerkelijk in een vroege fase samen te werken met marktpartijen. Vergeleken met de marktconsultatie gaat deze optie meer over samenwerking, daarnaast is er een vergoeding voor de opdrachtnemer. De (circulaire) opgave moet echter wel geschikt zijn, aangezien de concurrentiegerichte dialoog vaak meer dan een jaar duurt.
- Een **bouwteamovereenkomst** is een optie om samen te werken met de opdrachtnemer. Tijdens het bouwteam kan bijvoorbeeld de sloopaannemer aanwezig zijn om de kansen voor demontage en hergebruik te beoordelen. Daarnaast maakt het bouwteam risico's bespreekbaar, al betekent dit niet dat een bouwteam het probleem rondom risico's en risico's dragen oplost.
    - Bouwteamovereenkomst tijdens project veel benoemd als geschikte samenwerkingsvorm door opdrachtnemer

Risico, samenwerking en circulaire oplossingen/innovatie

- Circulaire projecten gaan gepaard met een risico. Wil men op korte termijn circulaire innovatie, dan is een lagere TRL noodzakelijk en moet de provincie meer risico durven te nemen.
- Wil men op lange termijn circulaire oplossingen, dan is bijvoorbeeld een raamovereenkomst geschikt. Zodoende kunnen circulaire oplossingen op meerdere projecten (portfolio aanpak) toegepast worden en heeft de opdrachtnemer de mogelijkheid om zijn innovatie te verbeteren.